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The Use of Business Intelligence Techniques in Supply Chain Performance

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ABSTRACT

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Who likes data? Businesses are always loyal data followers. Companies analyze various forms of data to maintain businesses and identify their current performance in different areas so they can find business opportunities to improve and obtain more market share in advance (Qrunfleh & Tarafdar, 2012). When Big Data comes to businesses, companies who can take advantage of data the best tend to regularly get more business and customers (Waller & Fawcett, 2013). Collecting, analyzing, and demonstrating data could be essential to a single business, a company's supply chain performance and its sustainability. As an intelligent data processing product in terms of information technology, business intelligence (BI) offers one of the more advanced solutions to face this challenge. The purpose of business intelligence is to improve the information quality and help users make better decisions on business processes by using data (Ranjan, 2009). This study was conducted to examine the use of business intelligence techniques in supply chain performance across various companies, departments and industries. The research also compared different BI vendors and their products. The purpose of this study was to conduct an online survey based on a supply chain performance benchmark to

mainly evaluate manufacturing and information technology companies and their user experience of BI techniques.

CHAPTER 1. INTRODUCTION

This chapter serves to introduce the research question, the purpose and the scope of the thesis research. It also presents some underlying assumptions, limitations and delimitations. Additionally, this chapter discusses some of the potential impact that the research has for the field. Following that, some definitions of key concepts was given.

1.1. Research Question

How does the use of decision-making analytical tools during the supply chain processes influence supply chain capabilities? How should one apply these tools to improve supply chain performance of global companies in order to reduce cost and increase profitability in today's dynamic market?

1.2. Statement of Purpose

As efficiency in global industry evolves, supply chain performance becomes the key factor for a company's failure or success; this is particularly true for high technology companies. Although these companies tend to invest large amounts of money in research and development, few of them are able to catch customers' real needs due to high costs (Arizona Department of Commerce, 2008). There is always a need to improve supply chain performance so these firms can survive the dynamic market with lower costs and

greater benefits. In order to improve the supply chain processes including forecasting, designing, purchasing, production, and marketing, appropriate decision-making based on the use of specialized analytical tools developed to simulate, analyze, visualize and optimize supply chain performance is still in its infancy. It is interesting to study how to apply and analyze these specialized decision-driven tools to help global companies improve their supply chain capabilities so as to create innovation and effective operation management, and increase their competitive advantages – especially supply chain performance (Oliveira, McCormack, & Trkman, 2012). Supply chain performance can be measured by a few key performance indicators such as inventory level, daily sales quantity and warehouse capacity. It is critical to determine which indicators would be useful for those decision makers seeking to implement efficient and effective supply chain tasks. The comparison of the selected performance indicators of the entire decision making process both using and not using analytical tool shows its importance to explore and emphasize the significance of the use of these specialized analytical implementations.

1.3. Significance

Much research has been performed on how business intelligence (BI) improves supply chain performance, but there are few studies identifying which KPI of the BI system could be beneficial to the improvement of the supply chain and be fitting to the supply chain operations reference (SCOR) model. In fact, due to the applications of various industries, sizes of companies, different countries and levels of supply chain, the wide range of the benchmark model might not be dynamic enough to analyze supply chain performance for every company (Persson, 2010). This research expands the

knowledge of the influence of detailed real time KPI by using BI on supply chain performance. The results of the study provide an analytical solution for companies to better forecast KPI, optimize business decision making, improve supply chain performance, obtain more competitive advantages, and gain more financial benefits in today's dynamic market and the Big Data Era (Waller & Fawcett, 2013). Moreover, although a variety of ERP, SCM and BI software and tools are developed by different companies, each product has its own characteristics and unique benchmarks for individual users. This research evaluated these existing BI products by focusing on comparing SAP with Oracle to obtain their applications and how these BI products apply the SCOR model as a best practice model, which fills the gap to research the supply chain analytics performance of BI products in the industry based on the widely recognized benchmark SCOR. The results of the research may help these software companies develop more effective and valuable BI techniques for the future, and may also help increase the reliability and feasibility of the SCOR model by utilizing theoretical strategies to execute practical operations in industry.

1.4. Scope

This research was conducted to study how business intelligence (BI) techniques influence and improve supply chain performance. It was limited to companies in industries that commonly have four horizontal layers including manufacturer, supplier, wholesaler, and retailer. Companies with global supply chain and large amounts of capital were studied to evaluate the complexity and comprehensiveness of the global supply chain system (Trkman, McCormack, Oliveria, & Laderia, 2010). Then, companies

were considered to be within scope if they used BI techniques to make decisions on their operational and supply chain related tasks by analyzing visualized real time data especially through key performance indicators (KPI) instead of analyzing traditional data such as annual or monthly reports for supply chain management (Cai, Liu, Xiao, & Liu, 2009). In this research, BI techniques within supply chain management were not limited, but focused on enterprise resource planning (ERP) system software and tools such as SAP, IBM and Dashboard. Other similar techniques that companies use to implement supply chain analytics were also considered as alternatives to represent BI techniques. Additionally, the supply chain operations reference (SCOR) model produced by Supply Chain Council (SCC) was used as a benchmark to measure the supply chain performance of these companies, and other comparable models were considered as additional references. Due to the need of case analyses, questionnaire-based surveys and publications of companies, the researcher only used the results and conducted qualitative analysis after obtaining permission from selected companies.

1.5. Assumptions

This study was designed with the following assumptions in mind:

- Participants were willing to try their best to answer the survey questions or share their knowledge and experience in the research topic.
- Participants avoided conflicts of interest and were honest in completing the survey when estimating performance measurement.
- Participants did not influence other participants' answer.

- Participants are able to read, write, and understand the English language that was used to write the survey.
- Each participant is a full time employee of the company.

1.6. Limitations

This study was constrained by the following limitations:

- The results of this study were limited by the responses of the survey and the permission of the companies.
- The study was limited by the cooperation and availability of the participants and their supervisors.
- The results of this study were limited by the use conditions of the business intelligence techniques.

1.7. Delimitations

This study had the following delimitations:

- The study only investigated the participants in companies with global supply chain operations systems in the United States.
- The study used the supply chain operations reference model (SCOR) as the only benchmarking tool to measure performance.
- New graduate students, employees, and participants without relevant BI experience were not included in the study.

1.8. Definitions

Business Intelligence (BI) - "A term that encompasses a broad range of analytical software and solutions for gathering, consolidating, analyzing and providing access to information in a way that is supposed to let an enterprise's users make better business decisions" (Sahay & Ranjan, 2008, p.30).

Data Mining (DM) - "DM is the process to mine the implicit, previously unknown, and valuable knowledge and rules for decision making from a large number of, incomplete, vague, and random practical application data stored in the data warehouse" (Liu, 2010, p.25).

ERP Systems - "ERP systems are transaction-processing focused and weak on analytics" (Liang & Miranda, 2001, p.15).

Online Analytical Processing (OLAP) - "OLAP provides multidimensional, summarized views of business data and is used for reporting, analysis, modeling and planning for optimizing the business" (Sahay & Ranjan, 2008, p.32).

Supply Chain Analytics - "The concept of supply chain analytics promises to extract and generate meaningful information for decision makers in the enterprise from the enormous amounts of data generated and captured by supply chain systems" (Sahay & Ranjan, 2008, p.37).

1.9. Summary

This chapter addressed states the scope, significance and purpose of this study. Primary limitations, delimitations, assumptions and definitions were described.

CHAPTER 2. REVIEW OF LITERATURE

2.1. Background

This chapter reviews literature on the research topic including supply chain performance and measurement, business analytics, and their applications in different industries and firms. It provides a background introduction of supply chain performance and measurement, an overview of Supply Chain Operations Reference (SCOR) model, a review of business analytics and its impact on supply chain performance. It also presents the use and influence of key performance indicators (KPI) and dashboards as the implementation of business analytics on improving supply chain performance. Many diverse academic resources were considered for this review including journals, papers, databases and graduate theses. The types of research contain surveys, simulation, case studies, conceptual models, mathematical models, reviews, performance metrics and content analyses.

2.2. An Overview of Supply Chain Performance and Measurement

In today's world, businesses face many challenges due to intense competition not only between companies but also between supply chains. In order to obtain more market share and possess stronger competitive advantages, the need to strengthen supply chain performance is increasing day by day. Today, the improvement of supply chain

performance is not only a concern of the individual company. Any upstream or downstream element of the supply chain could have a critical issue that affects the supply chain performance including suppliers, manufacturers, and wholesalers (Cai, Liu, Xiao, & Liu, 2009). Li (2007) and Zhang, Wang, Li, Wang, Wang, and Tan (2011) claimed in their research papers, supply chain management consists of synchronized decisions and activities that aim to realize goals for particular products or services, quantities, locations, prices, conditions, information and time to satisfy customer requirements by integrating end-to-end processes with minimum costs. Therefore, supply chain coordination and information technologies seem necessary to monitor and optimize supply chain performance. Management processes such as identifying measure parameters and targets, planning, defining communication methods, reporting and feedback have been embedded in different information system environments including SAP and Oracle (Cai *et al.,* 2009). With the help of these information technologies, performance measurement processes could help decision-makers and executives of companies to increase effectiveness and efficiency on their supply chain by focusing on different measurement metrics (Cai *et al.,* 2009). In general, performance measurement is vital in supply chains. Gunasekaran and Kobu (2007) mentioned that performance measurement could help identify customer needs and increase product or service fulfillment, understand supply chain processes, identify bottlenecks and improvement opportunities, make data-based decisions and enhance process communication and coordination.

However, it is not easy to conduct performance measurement and ensure supply chain performance quality, though quality assurance determines the success of supply chain management. Business is now becoming more dynamic and facing many

challenges as a result of globalization, which leads to complex supply chain systems. For example, Rekik (2011) discussed how inventory forecasting is still inaccurate in the wholesale supply chain even though large amounts of investment have been put into information technology. He found that advanced identification systems such as RFID technology could be very beneficial to forecast inventory and reduce bullwhip effects for certain conditions.

Some researchers conducted research on a few measures for ensuring supply chain quality through strategic planning, tactical employment and operational tools. They found that supply chain coordination, technology application, risk management, reliability assurance are important for continuous supply chain quality management (Zhang *et al.*, 2011). Akyuz and Erkan (2010) performed a literature review on supply chain performance measurement, intending to explore different research methodologies and approaches, potential opportunities to improve for the supply chain performance management. They suggested that companies focus on agile and flexible performance measurement methods due to the internal and external integration in companies, especially by merging supply chain management and the Internet. Internet-based intelligent technologies provide business interactions with autonomy, interactivity and pro-activity to improve the performance of supply chain optimization and information sharing (Zhang *et al,* 2011). Qrunfleh and Tarafdar (2012) indicated the positive effect of information system strategies on supply chain performance by conducting quantitative research. Furthermore, Yang (2012) issued a survey-based quantitative research paper regarding a hypothetical structural model of supply chain performance in a new market to assess how the level of information sharing influences supply chain performance. The

results revealed significant moderating effects on cost and innovation orientations on supply chain capabilities could improve the supply chain performance (Yang, 2012). Researchers also mentioned that the supply chain integration on information sharing can enhance the supply chain performance (Kocoglu, Imamoglu, Ince, & Keskin, 2011).

Yet, even though the information technologies have strong potential to improve performance measurement capabilities, some challenges in this area are unavoidable. According to Cai et al. (2009), first, it is hard to figure out which measurement should be identified by managers or decision-makers as key performance indicators (KPI). Second, it is necessary to explore the relationships between the selected KPIs because some measures are coupled or correlated. Third, practical problems might not be solved completely due to incomplete information, imperfect solutions and ineffective execution. Based on these research findings, Vallet-Bellmunt, Martínez-Fernández, and Capó-Vicedo (2011) pointed out that a higher level of supply chain maturity means the companies are able to recognize "how" and "why" these relationships between various processes and measures are produced within the supply chain. That is to say, systematic thinking applied to analyze supply chain performance and measurement would offer a comprehensive perspective and then enable companies to produce agile responses and effective solutions once they discover the improvement opportunities or potential problems of their supply chain at different levels.

2.3. SCOR Model

As Hwang, Lin, and Lyu (2008) explicitly explained, the supply chain operations reference (SCOR) model, launched by the supply chain council (SCC), is a cross-country

systematic standard for measuring and analyzing supply chain performance. SCOR has been applied and studied by different industries and organizations to enhance supply chain integration and information sharing between organizations. This model benefits companies all over the world in developing various performance metrics to increase their supply chain capabilities based on providing the best practice of performance evaluation. Suppliers, manufacturers, retailers, distributors, logistics service providers and customers all could help improve the effectiveness and efficiency of supply chain during planning, sourcing, manufacturing and delivering processes due to the SCOR model (Akyuz & Erkan, 2010; Hwang, Lin, & Lyu, 2008). In the study conducted by McCormack and Lockamy (2004), the SCOR model is used to illustrate that planning, collaboration, process measures and integration, process credibility and information technology all have an impact on the supply chain performance. Hwang et al. (2008) performed a questionnaire-based case study of an electronics manufacturing company in Taiwan by implementing regression analysis and analyzing key performance metrics at different levels of the SCOR model especially focusing on sourcing process. They also suggested following steps for the institutionalization of the SCOR model, such as establishing source planning project scope, using performance metrics to forecast and optimize supply chain to achieve best practices, and improving continuously by applying change management approaches. Although SCOR has been recognized as a benchmark for identifying, analyzing and examining supply chain performance, it still has some limitations: first, it's hard to trade off different performance measures and strategies for various users; second, the SCOR model does not identify cause-effect relationships among various key performance measures; and third, decision makers might not achieve

performance goals due to the inefficiency of choosing or analyzing critical KPIs (Cai *et al.*, 2009).

2.4. Business Intelligence in Supply Chain Analytics

Supply chain management developed quickly over time from traditional purchasing and supply management to the integration from raw materials to end user management (Liu, 2010). It is essential to analyze large amounts of information within the supply chain to identify financial conditions and information sharing and decision making capabilities. Under this condition, business intelligence (BI) has been developed in western countries from the middle of the 20th century. Liu (2010) clearly described business intelligence as a decision driven integrated technology by analyzing data to help companies improve business processes and optimize supply chain integration by including supply demand management, resource selection management, product definition, production management, inventory management, sales management, relationship management and decision making analysis. Sahay and Ranjan (2008) pointed out in their paper that BI is a collection of analytical software and solutions for real time information gathering and analyzing to help users make better business decisions for companies, both internally and externally. Business intelligence analysis is a complex set of techniques that cover data extraction and transition, database management, data mining and recovery, data reporting and visualization, and multidimensional analysis (Liu, 2010; Sahay & Ranjan, 2008). Among these, online analytical processing (OLAP) is critical to the concept of business intelligence. Sahay and Ranjan (2008) described query and reporting tools as key components of BI as follows:

> OLAP provides multidimensional, summarized views of business data and is used for reporting, analysis, modeling and planning for optimizing the business. OLAP techniques and tools can be used to work with data warehoused or data marts designed for sophisticated enterprise intelligence systems. These system process queries are required to discover trends and analyze critical factors. Reporting software generates aggregated views of data to keep the management informed about the state of their business. Other BI tools are used to store and analyze data, such as data mining and data warehouses; decision support systems and forecasting; document warehouses and document management; knowledge management; mapping; information visualization, and dash boarding; management information systems, geographic information systems; trend analysis; software as a service (p. 32).

Through business intelligence techniques, key performance measures such as material quantity, delivery cost, cost of goods, inventory turnover rate could be estimated in real time. In this way, companies can make better decisions on business tasks and activities; meanwhile improving customer and supplier relationship management and increasing supply chain flexibility to ensure the minimizing of overall costs and maximizing of overall profits. Liu (2010) also stated that BI might help companies achieve a balanced supply chain that maintains normal production and supply so that companies are able to achieve smooth cash flow. BI also supports information sharing and supply chain integration to predict more accurate customer demands by using real time data analysis and supply chain activities, and performance evaluation of the

participants in the supply chain, especially suppliers (Liu, 2010). A high level of supply chain integration would bring more competitive advantages and maximize the benefits of suppliers, manufacturers, wholesalers, logistics service providers and retailers in the supply chain. In particular, this could work when businesses and the environment become more dynamic and complicated. The capability of companies that implement business intelligence techniques on their supply chain is called supply chain analytics, which integrates different processes such as planning, sourcing, making and delivery to analyze supply chain performance (Sahay & Ranjan, 2008). Also, supply chain analytics aims to extract massive real time data collected by the supply chain system and generate meaningful information for decision makers in the supply chain (Sahey & Ranjan, 2008).

In Sahay and Ranjan's (2008) paper on business intelligence in supply chain analytics, they mentioned it is critical to enhance the effectiveness and efficiency of supply chain analytics by using a BI approach in a company. In this way, the company could achieve a competitive advantage because such practices would support supplier management and reduce costs. Additionally, supply chain analytics could help generate other advantages including increased production efficiency, optimized logistics and a more balanced inventory level. They also found a lot of companies were planning to invest capital to establish their own business intelligence systems. However, the results of huge investments in enterprise resource planning (ERP), supply chain management (SCM) and customer relationship management (CRM) are not always positive due to incomplete information and unsatisfactory forecasting (Sahey & Ranjan, 2008). Thus, in order to survive in the dynamic global market and unpredictable market conditions, companies need to have accurate forecasting and timely information so they can collect and analyze

real time data to make better and more correct decisions on their business activities (Gangadharan & Swamy, 2004; Moss & Atre, 2003).

Additionally, Sahay and Ranjan (2008) introduced the goal of real time business intelligence of applying data analytics to benefit decision makers, executives and participants in the supply chain with their tasks. They also cited a graph of the business intelligence infrastructure (shown in Figure 2.1) to explain the way in which how BI supports the business operation processes (Robinson, 2002). Departments such as operations, manufacturing, distribution and logistics, sales and marketing, finance and human resources are all allocated to different roles in the business intelligence system. Data processing involves four main steps: extract, clean, transform and load. Some examples of BI techniques are also as shown in Figure 2.1 below, such as balanced scorecards, query reporting and analysis, graphical trend analysis and scheduled reporting. Besides, business intelligence involves customer support, market research, distribution channels, product profitability, inventory and logistics analysis, statistical analysis and multidimensional reports. Data may come from various resources such as ERP, SCM and CRM system, customers, suppliers, manufacturing processes, new product testing and development, quality measurement and tasks, shop floor visiting and time studies, industry trading exchanges, market price forecasting, customer demographical allocation and purchased data from third party providers (Sahay & Ranjan, 2008). In particular, data such as customer demographic data, seasonal financial balanced sheets and inventory levels are all supposed to be thoughtfully analyzed to make appropriate decisions.

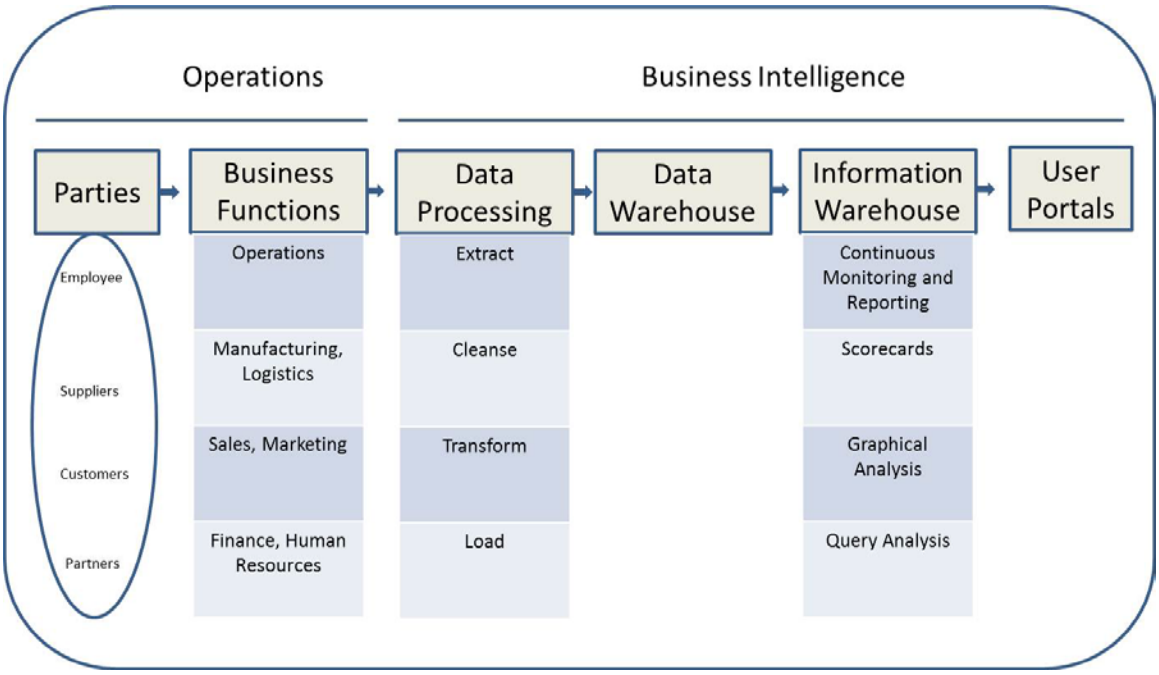

Figure 2.1. Business Intelligence Infrastructure (Robinson, 2002; Sahay & Ranjan, 2008)

Furthermore, with the development of business intelligence and information technology plus the complicated supply chain forms, companies start to become interested in big data real time analytics, and predictive analytics (Waller & Fawcett, 2013). Sivakumar (2007) and Sahay and Ranjan (2008) mentioned 57 percent of companies said they wanted to use their general company data warehouses to support their supply chain analytical applications, while 43 percent were using a separate supply chain analytics based data warehouse. Waller and Fawcett (2013) stated that big data predictive analytics involved in quantitative analysis, forecasting, optimization, expected values and uncertainty, patterns and relationships between a large amount of data and precise analyses based on hypothetical assumptions. In supply chain areas, predictive

analysis by utilizing business intelligence techniques with big data could be applied to predict timely inventory quantity, mean time to product failure, new product failure rate, monthly customer demands and orders, stock on the road, relationships between different KPIs and supplier strategies. Supply chain management predictive analytics could use big data to conduct both quantitative and qualitative methods to improve supply chain performance by estimating historical data and future levels of business processes (Waller & Fawcett, 2013).

Some relevant studies were conducted to discuss the impact of business intelligence techniques on the supply chain performance. For example, Hansoti (2010) analyzed the use of business intelligence dashboards for decision-making processes among various departments in different manufacturing organizations by conducting interviews and surveys with employees from those companies. Heydock's (2007) research on supply chain intelligence revealed opportunities to reduce costs and stimulate revenue growth by enabling companies to understand the entire supply chain from the customer standpoint. Heydock (2007) also described BI as a new initiative from data extraction to data analyzing that can enhance the executive ability to visualize the business status. Moreover, a relevant study mentioned by Sahay and Ranjan (2008) detailed, "a BI implementation generates a median five-year return on investment (ROI) of 112 percent with a mean payback of 1.6 years on average costs of $4.5 million" (p.43).

Trkman, McCormack, Oliveria, and Laderia (2010) validated the impact of business analytics on supply chain performance based on both quantitative and qualitative research. They studied the relationship between business analytics in the supply chain and the performance by using SCOR model, considering information system

support and business process orientation as moderators of this relationship. They developed a survey including questions about the key supply chain decision practices and their level of use in the supply chain with 310 participants from different industries and countries including China, USA, Canada, Brazil and some European countries (Trkman *et al.,* 2010). The research results showed that the use of business analytics in critical process areas could affect supply chain performance (Trkman *et al.,* 2010). The analytical capabilities can better guide the exclusively human decisions and provide automated decisions in some supply chain processes. In summary, companies that have better analytical capabilities with good information system tend to have better supply chain performance.

2.5. Business Intelligence Techniques

Ranjan (2009) issued a paper discussing the concepts, components, techniques and benefits of business intelligence. Ranjan states there are essentially two meanings of BI. One is to help humans make intelligent decisions in business activities so the organization can increase their overall performance; the other is to increase the value and quality of information so the organization can enhance communication among its departments. Ranjan (2009) also listed current BI techniques in her article, which including the following functions.

- Decision Support
- Data mining methods
- Statistical analysis
- Forecasting

- Online Analytical Processing
- Model visualization

Eckerson and Howson (2007) conducted a market analysis of the current BI techniques by listing market segments of the leading BI vendors and comparing their products. The results show that Microsoft, Oracle, SAP and SAS have the most supportive systems in the market in the technology portfolios of ERP systems, performance management, BI tools, data integration tools and relational database management systems. In Eckerson and Howson's (2007) opinion, some niche BI vendors will have many opportunities in the future to obtain some market share from the leading vendors due to their specialties and broad portfolios of BI capabilities. Singh and Nayeem (2011) investigated the worldwide BI vendor share from 2003 to 2008 and they found SAP, Business Objects, SAS, Cognos, IBM, Oracle and Microsoft all ranked ahead compared to other vendors. They (Singh & Nayeem, 2011) also mentioned that in the BI market, lots of acquisitions were made by these leading vendors to expand their BI capabilities from 2003 to 2008. For example, SAP acquired Business Objects in 2007 and Sybase in 2010; IBM acquired Cognos in 2007 and SPSS in 2009;Oracle acquired PeopleSoft in 2004, Seibel in 2005 and Hyperion in 2007; Microsoft acquired ProClarity in 2006. According to Howson (2012) from ASK LLC, the main BI products in these leading vendors were classified in Table 2.1. The information in Table 2.1 was adapted from tables used by Howson (p.2-p.9).

Table 2.1

BI products of the leading vendors

	SAP Business Objects	**IBM Cognos**	**Microsoft**	**Oracle**
Production Reporting	Crystal Reports, SAP Business Explorer Report Designer	Cognos Report Studio	Reporting Services Report Designer (in Visual Studio)	Oracle Publisher
Business Query and Reporting	Web Intelligence	Cognos Workspace and Business Insight	Report Builder Smart Client	Oracle Answers, BI Enterprise Edition
OLAP	Web Intelligence, SAP NetWeaver BW, Analysis Editions for OLAP	PowerPlay Sever TM1, Cognos 10 Workspace, Analysis Studio, Executive Viewer in Cognos Express	Analysis Services, Excel, PowerPivot, Performance Point, ProClarity	OLAP Option, OBBI EE Answers, Hyperion Essbase Exalytics
Dashboards	Dashboards, HANA, Web Application Designer	Workspace	Dashboard Designer, Performance Point, Sharepoint	Oracle BI Interactive Dashboards, Oracle Endeca Information Discovery
Performance Management	SAP Business Planning and Consolidation, Business Obejcts Financial Consolidations	Controller, Planning	NA	Hyperion Financial Manager, Hyperion Planning
Scorecards	SAP Strategy Management	Metrics Studio	Performance Point, Business Scorecard Manager	Oracle Scorecard and Strategy Management
Predictive Analytics and Data Mining	Business Obejcts Predictive Workbench, Predictive Analysis, HANA	SPSS	SQL Server, decision trees, clustering, Data Mining in Excel	Dada Mining for database or Essbase, Real Time Decision

Moreover, there is a gap between technology development and the use of technology. It is valuable to discuss technology adoption in terms of business intelligence. For example, for one of the BI functions, predictive analytics, Hapler (2014) addressed some challenges and barriers to the adoption of these techniques including the lack of skilled personnel, lack of understanding of technology, inability to assemble necessary data, the lack of a sufficient budget and strong business case, cultural issues, insufficient computing infrastructure, and steep learning curves. Under these conditions, Hapler (2014) suggested that building trust and collaboration is very important in adopting a new technology. The leaders in the organization should execute and build the best practices though the entire organization. Hapler (2014) also stated that understanding what the organization needs and utilizing different kinds of data will be beneficial to the predictive analytics adoption. She stated in addition to the development of data warehouse, it is also necessary to consider the mix of newer technologies by using different platforms and techniques, which constitutes a positive analytics ecosystem.

2.6. Survey

When researching supply chain performance and business analytics, a survey is a common tool to investigate the situations in specific organizations by the convenience sampling method (Akyuz & Erkan, 2010; Gable, 1994; Oliveira, McCrmack, & Trkman, 2012; Trkman *et al.,* 2010; Vallet-Bellmunt, Martínez-Fernández, & Capó-Vicedo, 2011). Speaking of different types of survey, Evans and Mathur (2005) listed online surveys, mail surveys, personal surveys, and telephone surveys. As they (Evans & Mathur, 2005) mentioned, an online survey has more flexibility and reachability, which could reduce the

response time and increase convenience for both investigators and participants. However, online surveys bring lower quality data. According to Evans and Mathur (2005), online surveys have low response rate. Yet, follow-up reminders can increase the response rate. In Ilieva, Baron and Healey's (2002) study, online surveys have a higher item completion rate than mail surveys due to the required completion function in online surveys. They also found answers to open-ended questions in online surveys are longer than in mail surveys. Yet, what kind of questions should be asked in the survey? Dolnicar (2013) addressed clear and simple questions are beneficial for researchers to examine the respondents' actual thoughts and situations including avoiding ambiguous, vague and long questions but well defining objects and attributes. Dolnicar (2013) also concluded that a combination of open-ended questions, multiple choices and Likert-scale questions provides descriptions from the respondents. According to Dawes (2008), a seven-point or a ten-point scale in a survey is a comparable method to measure the rater's actual perspectives. Additionally, Bartlett, Kotrlik and Higgins (2001) suggested if the survey results need factor analysis, it should be conducted with at least 100 participants. Yet, they also stated that budget, time and resource limitations present various constraints for researchers to get adequate sample sizes.

2.7. Summary

This chapter provided an overview of past literature regarding business intelligence and supply chain performance and analytics. It reviewed the concepts and background of supply chain performance, performance measurement and different performance metrics, basic applications of SCOR, introduction of business intelligence

and its impact on supply chain performance. Next, a review about current business intelligence techniques was conducted on markets. In addition to this, one review about how to appropriately conduct a survey was addressed in this chapter.

This literature review shows that supply chain analytics provides a broader view of an entire supply chain to produce products or service that can meet the customer's demands during different processes. Business intelligence techniques can help companies increase process efficiency and make better decisions for their supply chain strategies or business activities. Key performance metrics are critical to be identified over time by different sizes of the companies in different industries. The weakness of performance metrics involves the exploration of identification of KPIs and the relationships between various KPIs and qualitative issues within dynamic supply chain metrics. Work on this area is essential to the improvement of supply chain performance. The next chapter describes specific methodologies utilized in this thesis research.

CHAPTER 3. METHODOLOGY

This research studied the users involved in the supply chain process who are familiar with utilizing business intelligence techniques to help make decision on their supply chain operational activities in different organizations. The study specifically focused on the participants who apply business intelligence methods so that they could share their own experience of the influence of the business intelligence tools on supply chain performance, and compare the difference of main business intelligence platforms developed by different software vendors in the market such as SAP, IBM and Microsoft.

Due to the nature of the study, a qualitative research method with questionnaire-based analysis from multiple channels was conducted to ensure the reliability and quality of the research. This chapter describes the outline of the research methodology, data collection and analysis techniques of the research.

3.1. Framework

This study was conducted to analyze the relationships between business analytics in the supply chain and the performance in the supply chain operations reference model (SCOR), considering business intelligence techniques and performance measurement tools support. This study was based on firms in various industries that have complex supply chain networks and global operations (Oliveira, McCrmack, & Trkman, 2012;

Trkman *et al.*, 2010). In order to investigate the maturity of the supply chain of those participants' companies, the author utilized an existing validated survey as reference to redesign a new survey according to the research questions (Oliveira, McCrmack, & Trkman, 2012; Trkman *et al.*, 2010). As mentioned above, the survey had been already validated by discussions and interviews with multiple industry experts and practitioners selected by Supply Chain Council's member list (Oliveira, McCrmack, & Trkman, 2012; Trkman *et al.*, 2010). The only thing added to the previous survey was demographic questions about the participants including the use experience with BI techniques and their industry background. The validated survey contained the four levels of the SCOR model as a benchmark structure to measure the supply chain performance. The previous survey was validated by literature review, discussions with committee members and interviews with industry professionals and experts (Oliveira, McCrmack, & Trkman, 2012; Trkman *et al.*, 2010).

The following questions were examined in this thesis. The survey and literature review were two main resources used to explore these questions.

- What was the experience of these participants while using business intelligence techniques to make decisions on supply chain processes?
- Were these business analytic software developed according to the SCOR model so that the firms could import them into their own companies as benchmarking?
- What kind of key performance indicators would be strongly recommended to be shown in business intelligence tools to help improve the supply chain performance?

A key step was to synthesize the resources and collected data to build a benchmarking framework of different supply chain levels and to conduct a critical analysis on the use of business intelligence techniques. Two broad categories of research topics were as follows:

- The impact of business analytics on supply chain performance
- The comparison of different business intelligence software

3.2. Data Collection

This section provides the data collection techniques that were conducted to obtain a comprehensive knowledge of the research question. Both quantitative and qualitative types of data were collected in this research.

3.2.1. Academic Sources

Journal articles, conference proceedings papers and other publications were all important for this qualitative research because they provide various scientific ways to evaluate the research topic from a wide range of research methods and perspectives. It was beneficial to get professionals and related investigators to evaluate the research topic and determine effective research methods. According to the previous documentation, this specific research question involved empirical study, quantitative analysis, simulation, case study and structure modeling. Purdue University's library was a valuable research tool, as it offers sufficient databases to support researchers by granting access to these

academic sources. This allowed a greater exploration of specific topics and prior studies related to the research, which enhanced the quality of the qualitative research.

3.2.2. Survey

The population consisted of companies that were members of a supply chain and sourcing related association called Foundation for Strategic Sourcing and an online supply chain professional group called Supply Chain Analytics Intelligence. A convenience method was used (Akyuz & Erkan, 2010; Gable, 1994; Oliveira, McCrmack, & Trkman, 2012; Trkman *et al.,* 2010; Vallet-Bellmunt, Martínez-Fernández, & Capó-Vicedo, 2011). The participants were contacted by recruitment email (see Appendix A), and Linkedin post (see Appendix B) and the survey was administrated through Qualtrics. Company representatives from different departments answered the survey questions by giving a self-assessed performance rating on each item for each area including sales and marketing, purchasing and sourcing, manufacturing and production, logistics and supply chain, engineering and quality. The work experience and BI user experience of each participant varied in this study.

The survey instrument contained a seven-point scale measuring the frequency of practices (1 - never; 7 - always). Additionally, the participants were asked to either agree or disagree with the statement in the survey using a seven point scale (1- strongly disagree; 7 - strongly agree) to perform a self-assessed rating for the use of different BI techniques to make decision in four areas of SCOR model.

The participants were given a background information survey along with additional questions about supply chain performance indicators and the user experience

in business intelligence techniques. A follow-up email process was conducted during the data collection period based on the survey response progress.

The administration of the survey received approval of Purdue's institutional review board (IRB) (see Appendix C) by assuring the anonymity of the participants.

3.2.3 Additional Sources

Personal experience and observation from using business intelligence tools in a graduate level SAP analytics class supported the research. During the class, students were running an advanced real-time manufacturing simulation game by applying business intelligence techniques such as SAP Business Object software to help them make decisions on their supply chain operations.

In addition, different business intelligence vendors publish their product and market analysis report each year. These products and solutions' articles, white papers and case studies were also reviewed in this study to compare with the different BI tools and platforms.

3.3. Data Analysis

Survey questions included both descriptive demographical data and self-rated quantitative data. In this study, the demographical descriptions were analyzed for each individual participant. A summary of the participant responses was conducted to show the sample background information. For the SCOR model questions, the study collected all the quantitative data of the Likert Scale (Vagias, 2006). A statistical analysis of the

results of the research was conducted to evaluate the significance of the influence of business intelligence on supply chain performance. Pearson's correlation test was conducted to see the relationship between the SCOR analytics score and supply chain performance (Oliveira, McCormack, & Trkman, 2012). This study was included the comparison of BI beginners with experienced users, the comparison of manufacturing with information technology industries, which provided a more thorough investigation of the relationship between business intelligence use and supply chain performance, as well as the user experience of business intelligence techniques.

3.4. Summary

The purpose of this chapter was to describe the research methodology including the, research framework, data collection and analysis methods.

CHAPTER 4. DATA COLLECTION

This chapter describes the data collected from the online survey and market analysis of different BI products. The demographic information of each participant in this study is described. This survey demonstrates the effect of business intelligence techniques on supply chain performance, and the use experience of business intelligence among different individuals. The results of the study were reviewed to show the performance score within four SCOR areas in different companies and the comparisons with different BI platforms.

4.1. Participant Qualitative Description

This survey resulted in 16 responses within one month. 14 of the 16 are complete and valid responses. All the survey questions can be seen from Appendix D. The average completion time for the survey among all participants was 14 minutes 34 seconds. The following section introduces all the participants with their background questionnaire descriptions. The valid participants must have had some knowledge or work experience of business intelligence and their company must have had global supply chains as they state in the survey questions.

Figure 4.1 showed the different business functions of participants. Five of the total 14 participants were managers; three of them were the other positions including

order fulfillment, new product introduction, and lean facilitator; three of them were junior analysts; others were one senior analyst, one associate and one director.

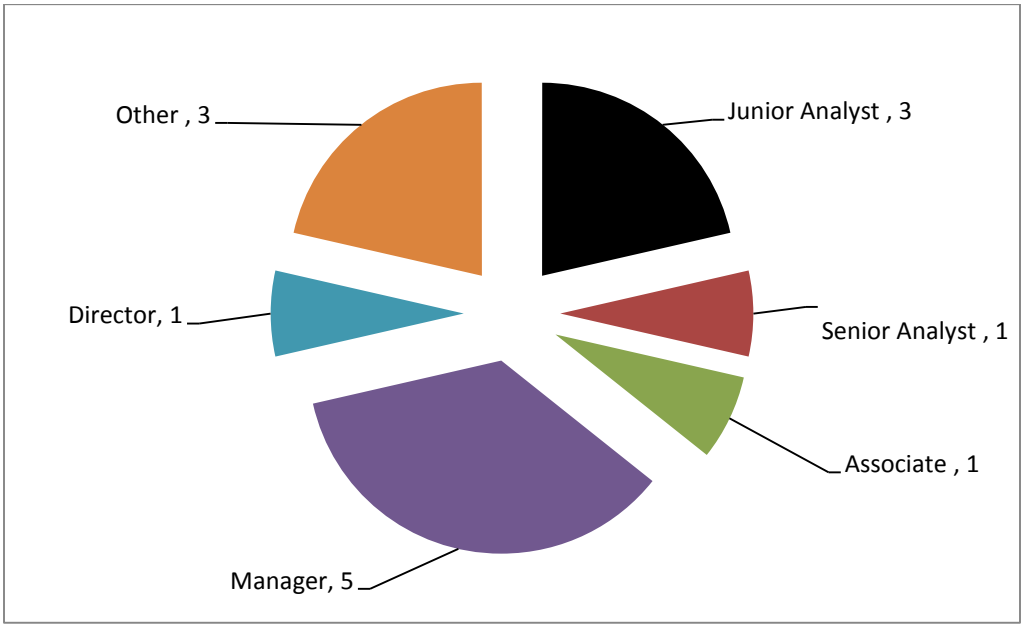

Figure 4.1. Respondent participants by different positions

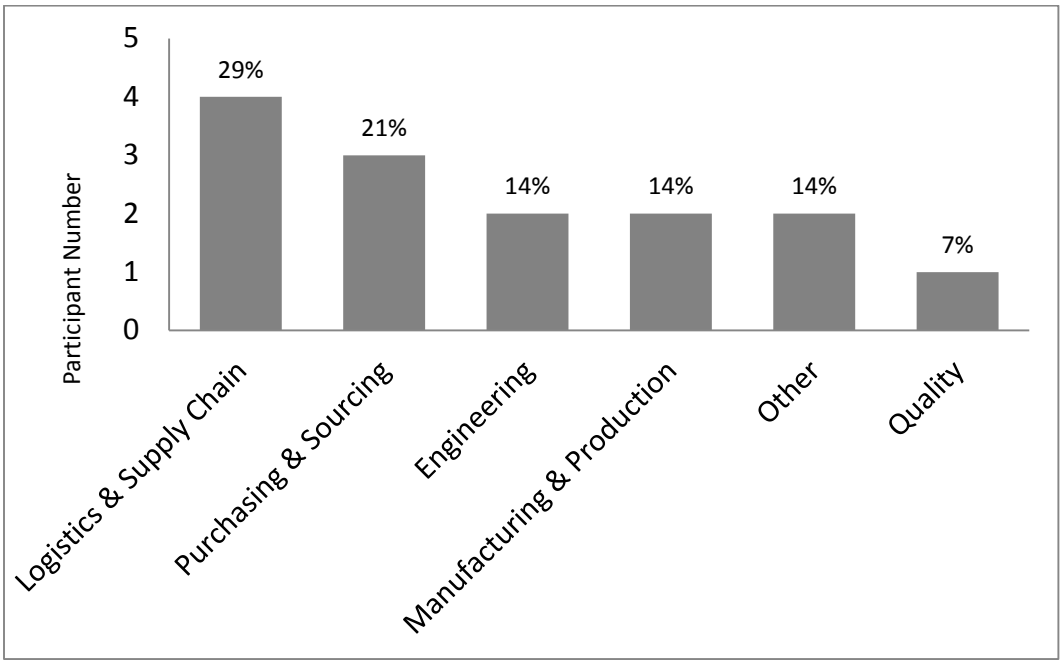

Figure 4.2. Respondent participants by different departments

From the total 14 participants, Figure 4.2 indicates the individuals were from different departments in companies including logistics and supply chain, purchasing and sourcing, engineering, manufacturing and production, product introduction, enterprise application development and quality.

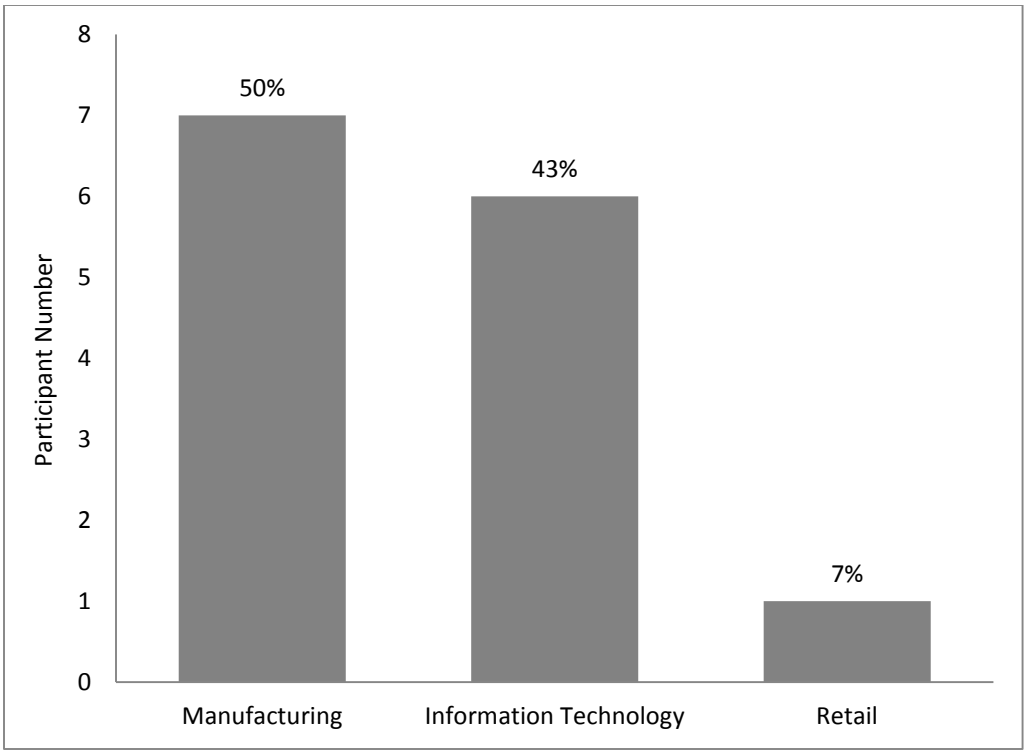

Figure 4.3. Respondent participants by different industries

Figure 4.3 demonstrates the participants came from three different industries based on self-selection. Seven were in the manufacturing industry; six were in the information technology industry; one was in the retail industry.

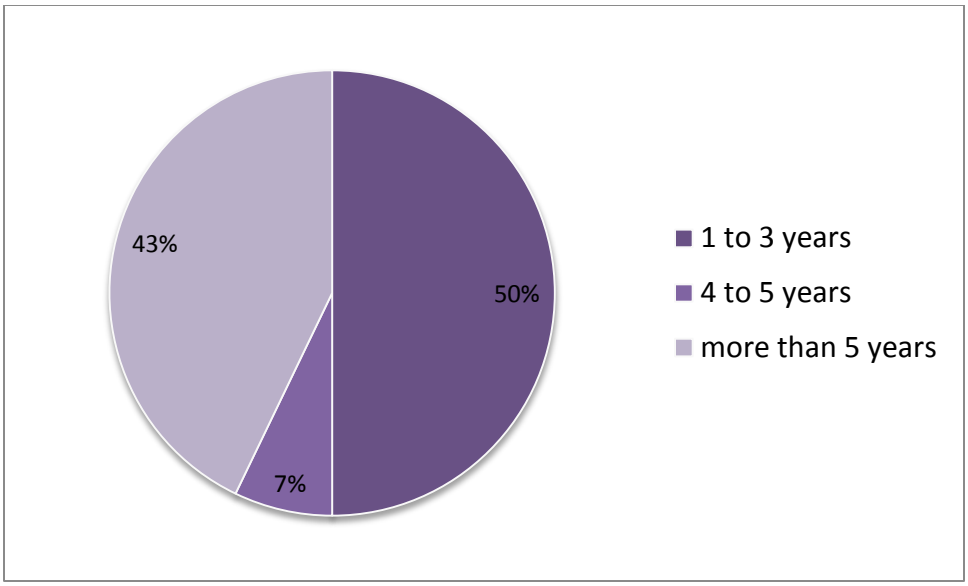

Figure 4.4. Respondent participants by different industry experience

Figure 4.4 shows clearly that all the participants have at least one year of experience working in the industry. Fifty percent of the participants had one to three years' work experience; forty-three percent had more than five years' work experience; and seven percent possessed four to five years' work experience. According to the survey results, all participants have worked with business intelligence software and techniques and their work involve in database.

4.1.1 Participant 1

Participant 1 was a female manager from the purchasing and sourcing department with four to five years' work experience in a manufacturing company. She stated that she had a basic technical knowledge with experience in Business Intelligence software and techniques as a beginner. Her company used SAP, IBM and Microsoft as the information system vendors. She personally used SAP Business Objects and Predictive Analysis in

her work as BI techniques. In her opinion, the use of BI software and techniques is a critical success factor and it can influence the whole organization's success.

4.1.2 Participant 2

Participant 2 was a female associate from the logistics and supply chain department with one to three years' work experience in an information technology company. She also stated that she had a basic technical knowledge with experience in Business Intelligence software and techniques as a beginner. Her company used IBM information system. She personally used Microsoft Excel and Access analytics, Brio and IBM Cognos in her work with BI techniques. In her opinion, the use of BI software and techniques can support business strategy, and influence the achievement of strategy over a long period.

4.1.3 Participant 3

Participant 3 was a female junior analyst from the quality department with one to three years' work experience in a manufacturing company. She considered herself as an intermediate user of Business intelligence software and techniques and she had experience of database. She also stated that her company used SAP and Microsoft information system. She personally used Dashboard analytics, SAP Business Objects and Predictive Analysis, and Microsoft Excel and Access analytics in her work as BI techniques. She also demonstrates that the use of BI software and techniques can supports business strategy, and influence the achievement of strategy over a long period.

4.1.4 Participant 4

Participant 4 was a male senior analyst from the logistics and supply chain department with one to three years' work experience in an information technology company. He considered himself an intermediate user of Business intelligence software and techniques with database experience. His company used IBM and Microsoft information system. He personally used Dashboard analytics and Microsoft Excel and Access analytics in his work in BI techniques. He believed the use of BI software and techniques is a critical success factor and it can influence the whole organization's success.

4.1.5 Participant 5

Participant 5 was a female order fulfillment employee from the logistics and supply chain department with one to three years' work experience in an information technology company with work experience in database and Business Intelligence techniques. She stated she had basic knowledge Business intelligence software and techniques as a beginner. Her company uses a combination of SAP, IBM and Microsoft information systems. She personally used SAP Business Objects and Predictive Analysis and Microsoft Excel and Access analytics in her work with BI techniques. She thought the use of BI software and techniques helped them maintain their current platform which had not a major influence on operations.

4.1.6 Participant 6

Participant 6 was a male junior analyst from the engineering department with one to three years' work experience in a manufacturing company. He had an intermediate technical knowledge of business intelligence software and techniques and worked with databases previously. His company used only IBM information systems. He personally used Microsoft Excel and Access analytics in his work as BI techniques. He believed the use of BI software and techniques is a critical success factor and it can influence the whole organization's success.

4.1.7 Participant 7

Participant 7 was a female new product introduction employee from the product introduction department with more than five years' work experience in an information technology company with work experience in database and Business Intelligence techniques. She had a basic knowledge of Business intelligence software and techniques as a beginner. Her company used IBM information systems. She personally uses Dashboard Analytics, SAP Business Objects and Predictive Analysis and Microsoft Excel and Access analytics in her work as BI techniques. She thought the use of BI software and techniques can support business strategy, and influence the achievement of strategy over a long period.

4.1.8 Participant 8

Participant 8 was a female manager from the manufacturing and production department with more than five years' work experience in an information technology

company. She had basic technical knowledge of Business intelligence software and techniques and she had worked with database previously. Her company used a combination of SAP, IBM and Microsoft information system. She personally used Dashboard Analytics, SAP Business Objects and Predictive Analysis and Microsoft Excel and Access analytics in her work as BI techniques. She believed the use of BI software and techniques can support business strategy, and influence the achievement of strategy over a long period.

4.1.9 Participant 9

Participant 9 was a male manager from the enterprise application development department with more than five years' work experience in an information technology company and had work experience in database and Business Intelligence techniques. He considered himself an advanced user of Business intelligence software and techniques. His company only used an IBM information system and he used IBM Cognos in his work as BI technique. He thought the use of BI software and techniques can support business strategy, and influence the achievement of strategy over a long period.

4.1.10 Participant 10

Participant 10 was a female junior analyst from the purchasing and sourcing department with one to three years' work experience in a manufacturing company. She had a basic technical knowledge with experience in Business Intelligence software and techniques as a beginner. Her company used SAP information system. She personally used SAP Business Objects and Predictive Analysis, Microsoft Excel and Access

analytics in her work as BI techniques. In her opinion, the use of BI software and techniques has promoted minor improvements and influences business processes.

4.1.11 Participant 11

Participant 11 was a male manager from the engineering department with more than five years' work experience in a manufacturing company with work experience in database and Business Intelligence techniques. He considered himself an intermediate user of Business intelligence software and techniques. His company used SAP and Microsoft information system and he used a combination of Dashboard Analytics, SAP Business Objects and Predictive Analysis, Microsoft Excel and Access Analytics in his work as BI techniques. He indicated that the use of BI software and techniques can support business strategy, and influence the achievement of strategy over a long period.

4.1.12 Participant 12

Participant 12 was a male director from the purchasing and sourcing department with more than five years' work experience in a manufacturing company with work experience in database and Business Intelligence techniques. He had an advanced technical knowledge of Business intelligence software and techniques. His company used Exact information systems. He personally uses Dashboard Analytics, and Microsoft Excel and Access analytics in his work as BI techniques. He believed the use of BI software and techniques helps them maintain their current platform but not had a major influence on operations.

4.1.13 Participant 13

Participant 13 was a female lean facilitator from the manufacturing and production department with one to three years' work experience in a manufacturing company with work experience in database and Business Intelligence techniques. She had a basic knowledge of Business intelligence software and techniques as a beginner. Her company used ERP as information systems. She personally used ERP in her work as BI techniques. She thought that the use of BI software and techniques can support business strategy, and influence the achievement of strategy over a long period.

4.1.14 Participant 14

Participant 14 was a male manager from the logistics and supply chain development department with more than five years' work experience in a retail company with work experience in database and Business Intelligence techniques. He considered himself as an intermediate user of Business intelligence software and techniques. His company only used Microsoft information system and he used Dashboard analytics and Microsoft Excel and Access Analytics in his work as BI technique. In his opinion, the use of BI software and techniques can support business strategy, and influence the achievement of strategy over a long period.

4.2 Summary of Participant Qualitative Data

In this section, the participant qualitative data is reviewed. From Figure 4.5, fifty percent of total 14 participants consider themselves as beginners of BI users; thirty-six

percent thought they had an intermediate knowledge of BI techniques; fourteen percent addressed that they had a strong and advanced technical knowledge and experience of BI.

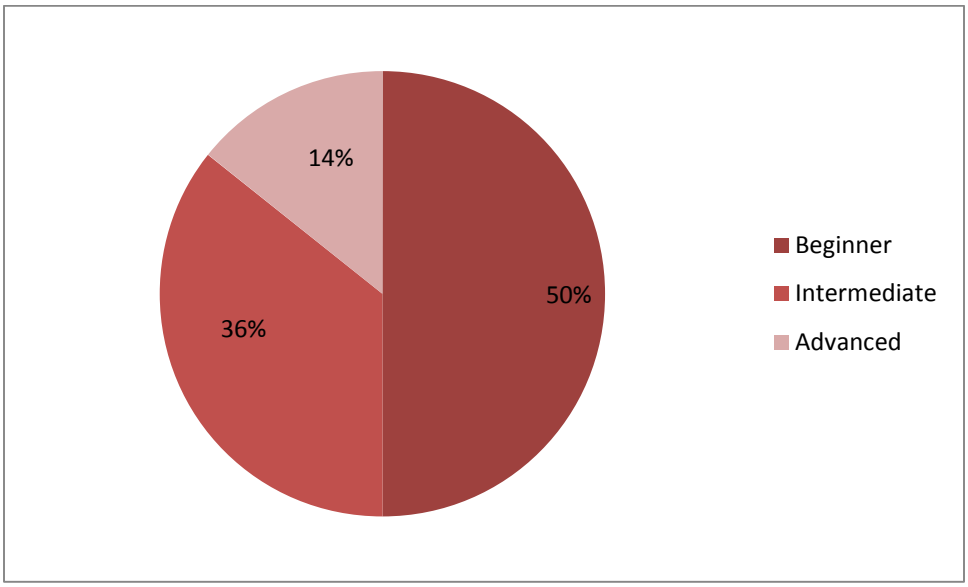

Figure 4.5. Respondent participants by different usage time period of BI techniques

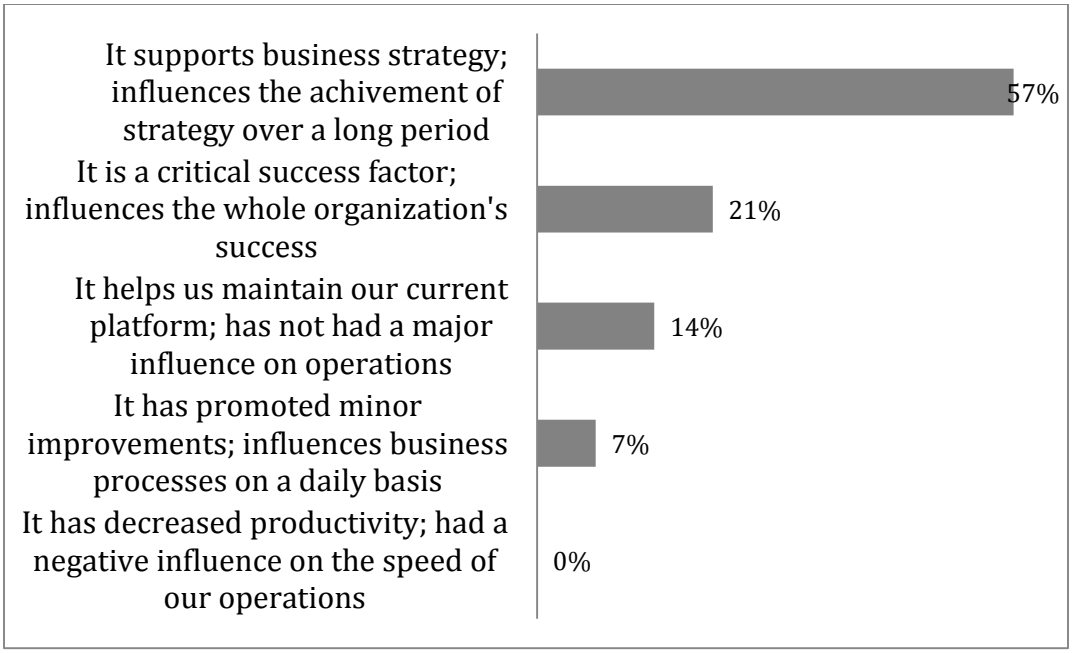

Figure 4.6. Response rate of participants for different opinions on the use of BI

Also, according to Figure 4.6, fifty-seven percent believed the use of BI software and techniques supports business strategy, and influence the achievement of strategy over a long period; twenty-one percent believed the use of BI software and techniques is a critical success factor and it can influence the whole organization's success; fourteen percent believed the use of BI software and techniques helps them maintain their current platform but not had a major influence on operations. Seven percent actually thought the use of BI software and techniques has promoted minor improvements and influences business processes on a daily basis; none of the participants believed the use of BI software and techniques had decreased productivity and had a negative influence on the speed of their operations.

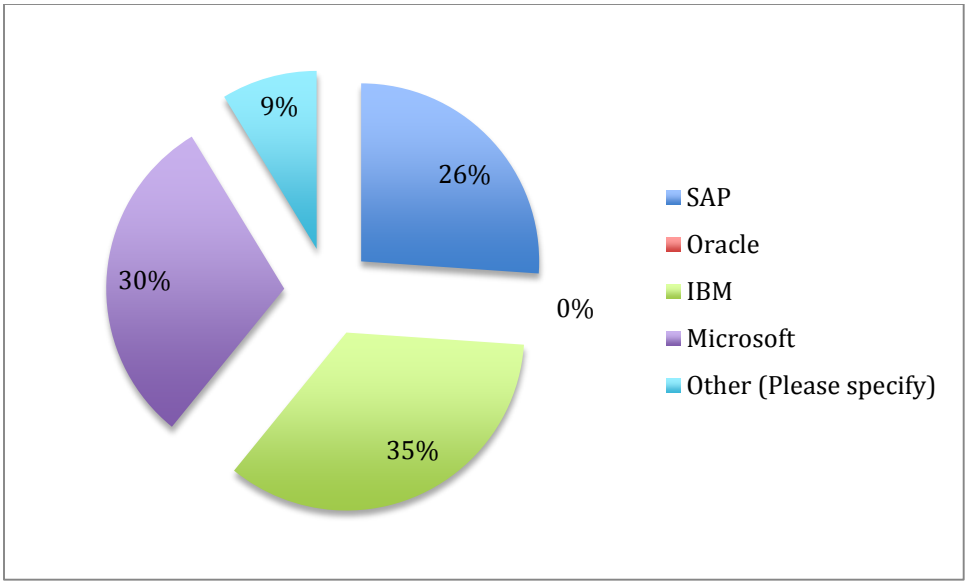

Figure 4.7. Respondent participants by different BI vendors

Figure 4.7 indicates that thirty-five percent companies use IBM as an information system vendor, thirty percent use Microsoft products, twenty-six percent use SAP, and

nine percent use other software. In this study, no participant used an Oracle system in their companies.

In terms of BI techniques, participants all have different views about the use of Business Intelligence. Figure 4.8 illustrates seventy-nine percent have experience with Microsoft Excel and Access Analytics, fifty percent use Dashboard analytics, fifty percent use SAP Business Objects and Predictive Analysis, and twenty-one percent use other BI techniques.

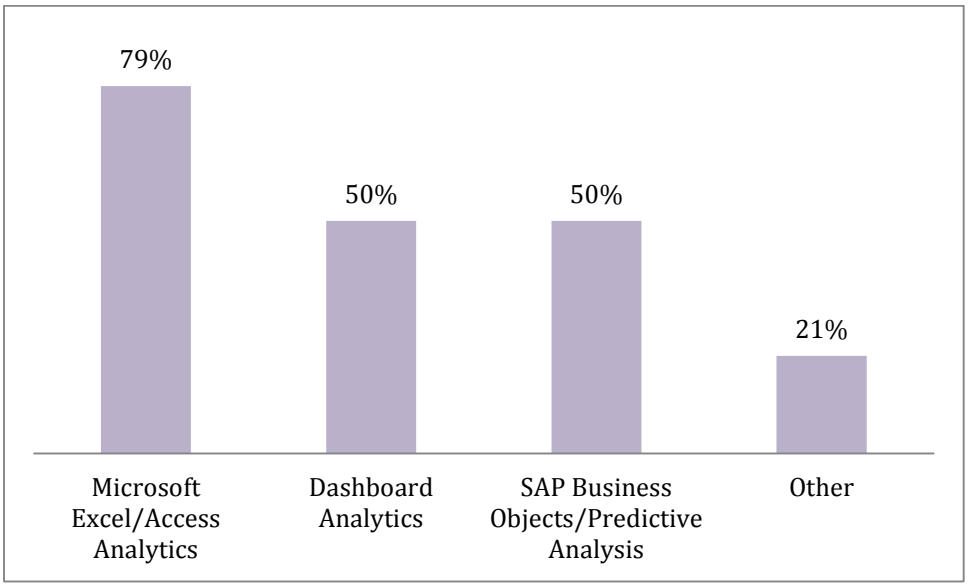

Figure 4.8. Responses of participants by different BI techniques

4.3. Quantitative Data from Survey

As the second part of the survey content, SCOR model based performance self-assessment question matrixes were examined including different areas – plan, source, make, delivery, information system support. In this section, each participant assesses the

performance based on their use of Business Intelligence in their companies. According to Vagias (2006), all the participants used a Likert scale range from one to seven (1 – never 0%; 2 – rarely 10%; 3 – occasionally 30%; 4 – sometimes 50%; 5 – frequently 70%; 6 – usually 90%; 7 – every time 100%). In the end questions were about an overall performance rate for all the areas used a Likert scale range from one to seven (1 – strongly disagree; 2 – disagree; 3; somewhat disagree; 4 – neither agree nor disagree; 5- somewhat agree; 6 – agree; 7 – strongly agree).

4.3.1. Plan Performance

In the SCOR model, the Plan process involves measuring, scheduling and forecasting. Participants were asked to assess 11 indicator questions related to Plan stage. Each question contained a seven point Likert scale (Vagias, 2006). By conducting the basic statistical analysis of each question, Table 4.1 displays that the standard deviations were relatively high between individual participants' assessments for each question. The lowest standard deviation was 1.10 which was with question P11, and the highest was 2.49 which was for question P10. For a total of 14 responses, the mean Likert score for each question was around 4 and 5, which means these indicators of Plan capabilities sometimes or frequently happened in the companies' daily operations. Table 4.1 also contains results illustrating that there is usually a large variance for different participants in assessing their companies. For instance, in question P1, the survey asked participants if they have established supply chain performance measures in the Plan stage based on the use of BI techniques.

Table 4.1

Descriptive performance score in Plan stage

Statistic	P1. Have you established supply chain performance measures?	P2. Do you review the impact of your plan's strategies on supply chain performance measures?	P3. Do you use adequate analysis tools to examine the plan's impact before a decision is made?	P4. Do you monitor customer profitability?	P5. Do you monitor product profitability?	P6. Do you analyze the variability of demand for your products?	P7. Do you use mathematical methods (statistics) for forecasting demand?	P8. Is a forecast developed for each product?	P9. Is a forecast developed for each customer?	P10. Does your demand management process make use of customer information?	P11. Is forecast accuracy measured?
Min Value	2	2	1	1	1	2	2	3	1	1	4
Max Value	7	7	7	6	7	7	7	7	7	7	7
Mean	4.36	4.64	3.93	3.79	4.07	5.07	4.64	5.07	3.79	4.29	5.14
Variance	2.71	2.25	2.07	2.18	3.30	2.69	2.86	1.76	4.03	6.22	1.21
Standard Deviation	1.65	1.50	1.44	1.48	1.82	1.64	1.69	1.33	2.01	2.49	1.10
Total Responses	14	14	14	14	14	14	14	14	14	14	14

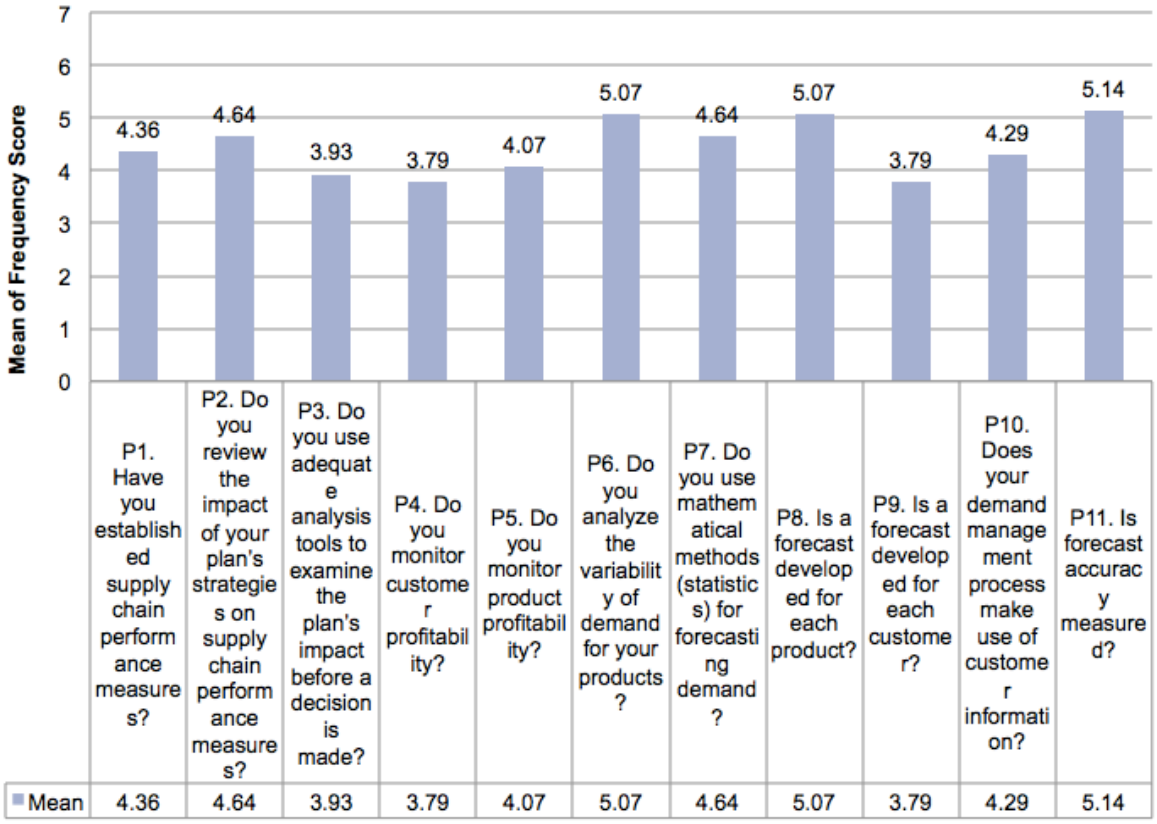

Figure 4.9. Mean performance score in Plan stage

The minimum value of total 14 participants was 2 which implies they rarely do the activity in question, and the maximum value was 7 which means they do it always. This condition is also consistent with other questions. In addition, Figure 4.9 clearly indicated all the mean frequency scores for each different indicator questions. P6, P7 and P11 received relatively high average values, which means companies in this study frequently analyze the variability of demand for their products, use mathematical methods for forecasting demand, and the forecast accuracy is frequently being measured accurately. However, P3, P4 and P10 received relatively low average values, which means companies in this study occasionally use adequate analysis tools to examine the Plan's impact before a decision is made, and they just occasionally monitor customer profitability during the Plan time. Their demand management processes do not very often make use of customer information to conduct analysis. These key performance indicators could influence the companies' Plan capabilities to some degree.

4.3.2. Source Performance

In the SCOR model, the Source process involves purchasing and supplier management. Participants were asked to assess 5 indicator questions related to Source stage and each question contained a seven point Likert scale. Upon conducting the basic statistical analysis of each question, Table 4.2 was created to show the standard deviations are relatively closer than the Plan stage. The lowest standard deviation was 1.88 which was with question S5 and highest was 1.98 which was with question S2 and S3. For total 14 responses, the mean Likert score for each question is around 4, which

means these indicators of Source capabilities have around 50% chances to happen in company's daily operations. Table 4.2 is used to illustrate there is usually a big variance for different participant assessing their companies.

Table 4.2

Descriptive performance score in Source stage

Statistic	S1. Are the supplier inter-relationships documented?	S2. Do you share planning and scheduling information with suppliers?	S3. Do you "collaborate" with your suppliers to develop a plan?	S4. Do you measure supplier performance?	S5. Do you give feedback based on supplier performance?
Min Value	1	1	1	1	2
Max Value	7	7	7	7	7
Mean	4.64	4.71	3.93	4.36	4.14
Variance	3.79	3.91	3.92	3.79	3.52
Standard Deviation	1.95	1.98	1.98	1.95	1.88
Total Responses	14	14	14	14	14

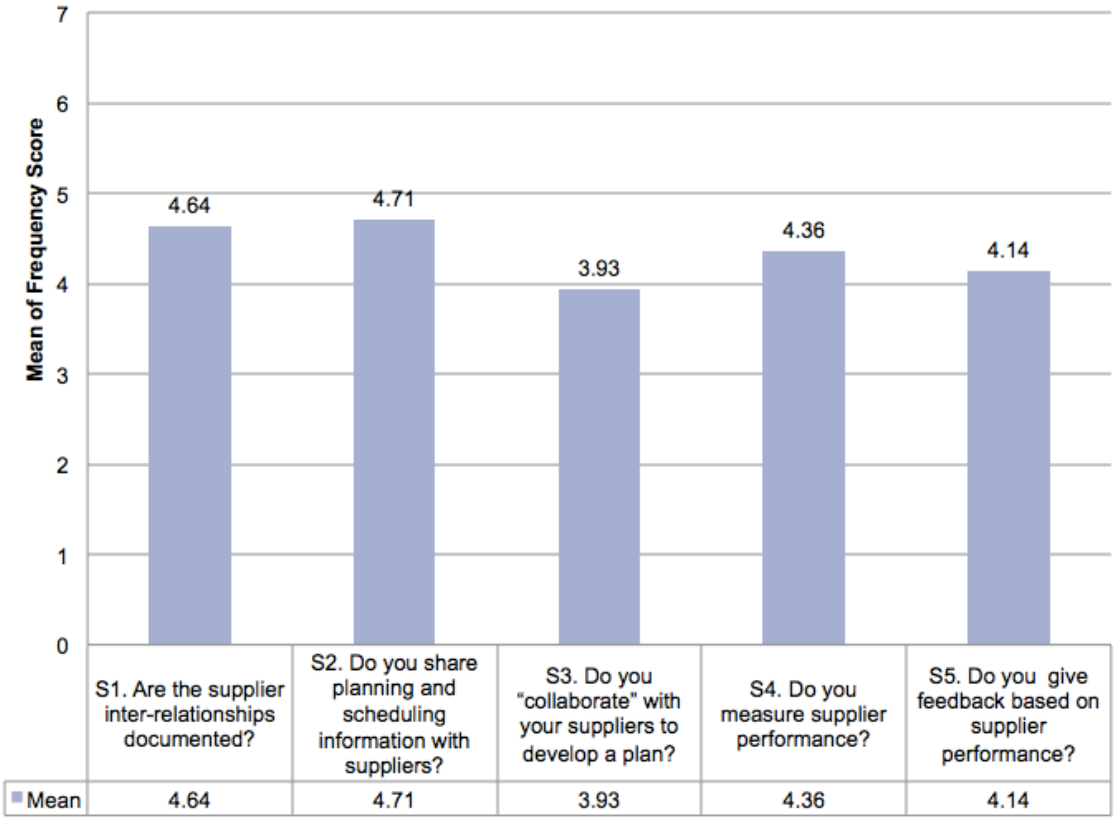

Figure 4.10. Mean performance score in Source stage

In addition, Figure 4.10 also contains all the mean frequency scores for each different indicator questions. Question S2 and S1 received the higher average value, which means companies in this study sometimes or frequently share planning and scheduling information with suppliers. More than 60% of the time, those companies document the supplier interrelationships. However, S3 and S5 received relatively low average values, which means companies in this study only sometimes measure supplier performance and give feedback based on supplier performance as well. There is always a space for companies to improve their analytics comprehensiveness and information technologies.

4.3.3. Make Performance

In the SCOR model, the Make process involves production, scheduling, operations, planning and measuring. Participants were asked to assess 7 indicator questions related to Make stage and each question uses a seven point Likert scale. Upon conducting the basic statistical analysis of each question, Table 4.3 was used to illustrate that standard deviations still vary in the Make stage. The lowest standard deviation was 1.36 which is with question M5 and the highest was 2.08 which was with question M6. For total 14 responses, the mean score for each question was around 4 and 5, which means these indicators of Make capabilities have around 50% chances to happen in company's daily operations. Table 4.3 also shows there is usually a big variance for different participant assessing their companies.

Table 4.3

Descriptive performance score in Make stage

Statistic	M1. Are your planning processes integrated and coordinated across divisions?	M2. Are supplier lead times updated weekly?	M3. Do you use constraint-based planning methodologies?	M4. Do you measure "adherence to plan"?	M5. Do the sales, manufacturing and distribution organizations collaborate in the planning and scheduling process?	M6. Is your customer's planning and scheduling information included in yours?	M7. Are plans developed at the "item" level of detail?
Min Value	1	1	1	1	2	1	1
Max Value	7	7	6	7	7	7	7
Mean	4.64	3.50	3.21	4.29	5.00	4.00	5.29
Variance	2.55	3.81	3.10	2.84	1.85	4.31	3.76
Standard Deviation	1.60	1.95	1.76	1.68	1.36	2.08	1.94
Total Responses	14	14	14	14	14	14	14

In addition, Figure 4.11 also indicates all the mean frequency scores for each individual indicator question. Question M5 and M7 get the higher average value, which means companies in this study frequently collaborate between different departments including the sales, manufacturing, and distribution organizations. More than 70% of the time, those companies develop plans at the product item level. However, M2 and M3 got relatively low average values, which means companies in this study only occasionally use constraint-based planning methodologies and their supplier lead times are not often updated weekly. This could generate future improvement for further analytics by BI techniques and updated information systems.

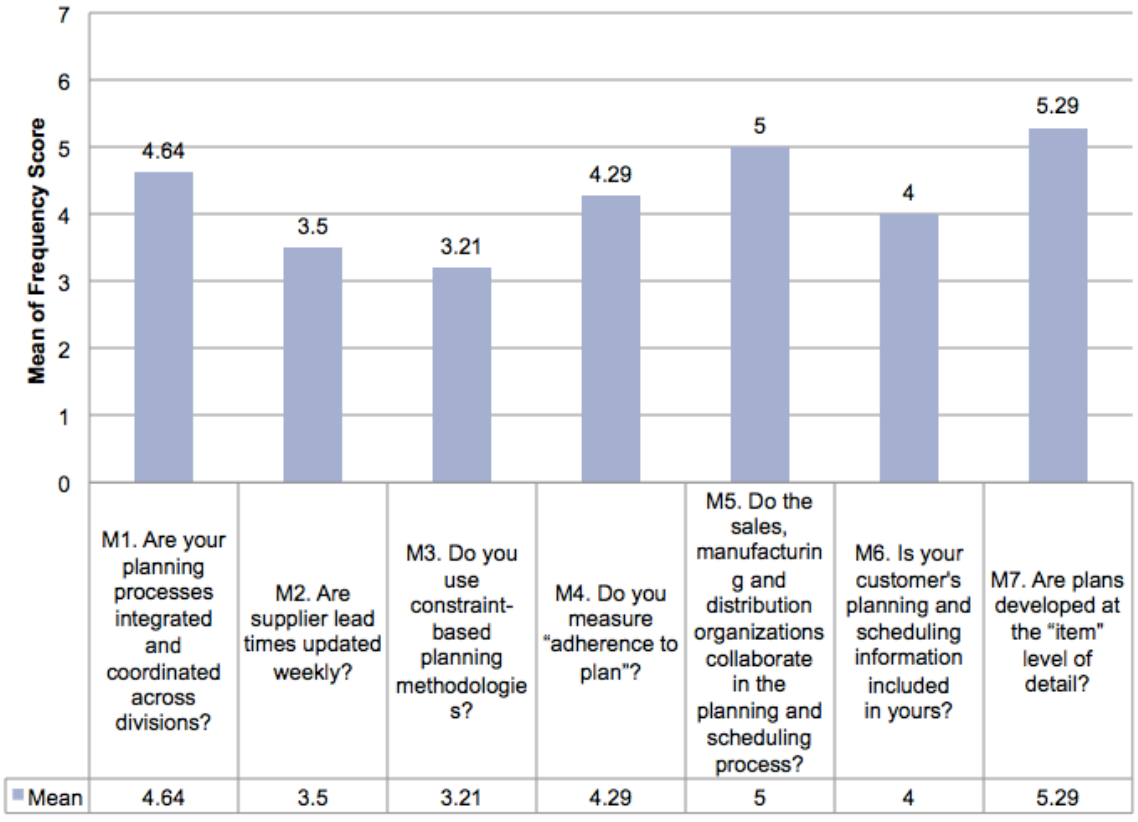

Figure 4.11. Mean performance score in Make stage

4.3.4. Delivery Performance

In the SCOR model, the Delivery process involves logistics, tracking, measuring, distribution and planning. Participants were asked to assess 6 indicator questions related to Delivery stage and each question used a seven point Likert scale. By conducting the basic statistical analysis of each question, Table 4.4 addressed the standard deviations still vary in the Delivery stage. The lowest standard deviation was 1.56 which was with question D1 and highest was 2.04 which is with question D2. For total 14 responses, the mean Likert score for each question were all above 4, which means these indicators of Delivery capabilities have more than 50% chances to cover the indicators in company's daily operations. Table 4.4 also shows the large variance for different participant assessing their companies.

Table 4.4

Descriptive performance score in Delivery stage

Statistic	D1. Do you track the percentage of completed customer orders delivered on time?	D2. Do you measure "out of stock" situations?	D3. Are the network inter-relationships (variability, metrics) documented?	D4. Do you use a mathematical "tool" to assist in distribution planning?	D5. Are distribution management process measures in place?	D6. Are process measures used to recognize the process participants?
Min Value	3	1	1	1	1	1
Max Value	7	7	7	7	7	7
Mean	5.50	5.21	4.36	4.29	4.50	4.21
Variance	2.42	4.18	3.63	3.30	3.81	3.41
Standard Deviation	1.56	2.04	1.91	1.82	1.95	1.85
Total Responses	14	14	14	14	14	14

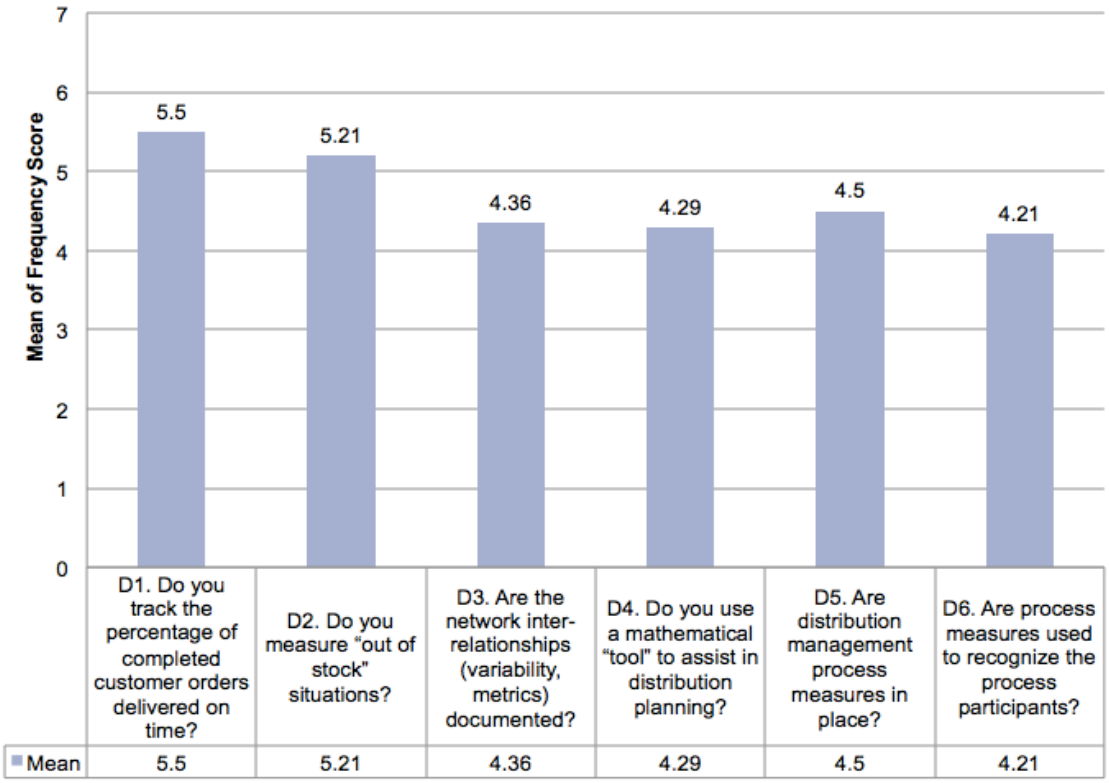

Figure 4.12. Mean performance score in Delivery stage

In addition, Figure 4.12 indicates all the mean frequency scores for each individual indicator question. Question D1 and D2 received a higher average value, which implies companies in this study more than frequently track the customer order status and measure the "out of stock" situations to manage inventory. Other indicators like network interrelationship metrics, mathematical based distribution planning and process measurement and process holder recognitions are sometimes checked by information system in these companies.

4.3.5. Information System Support Performance

As stated in the previous sections, this study mainly examines the BI based information system and its effect on supply chain performance. In this section, the survey asked participants 9 questions with the indicators of Information system support capabilities and still each question uses a seven point Likert scale. Table 4.5 shows the statistical analysis of each question and it shows mean value, standard deviation, minimum and maximum value of each question by different participants. The lowest standard deviation was 1.50 which was with question IS7 and highest was 2.16 which is with question IS3. For total 14 responses, the mean Likert score for each question was around 4, which means these indicators of information system support capabilities have around 50% chances to cover the indicators in company's daily operations.

Table 4.5

Descriptive performance score in Information System support

Statistic	IS1. Does your information system currently support the supply chain processes?	IS2. Does your information system currently support the order commitment process?	IS3. Does your information system support distribution management?	IS4. Does your information system currently support the process (Make)?	IS5. Does your information system support this process (Source)?	IS6. Does your information system currently support the demand management process?	IS7. Do you make decisions on supply chain processes using business analytics techniques?	IS8. Do you speed up your decision making process by using business analytics techniques?	IS9. Do you make decisions based on information sharing with other departments in the company by using business intelligence techniques?
Min Value	1	1	1	1	1	1	1	1	1
Max Value	7	7	7	7	7	6	7	7	7
Mean	5.14	5.14	3.93	5.00	4.36	4.07	4.43	4.29	4.36
Variance	2.90	3.52	4.69	2.77	3.32	1.92	2.26	3.14	2.71
Standard Deviation	1.70	1.88	2.16	1.66	1.82	1.38	1.50	1.77	1.65
Total Responses	14	14	14	14	14	14	14	14	14

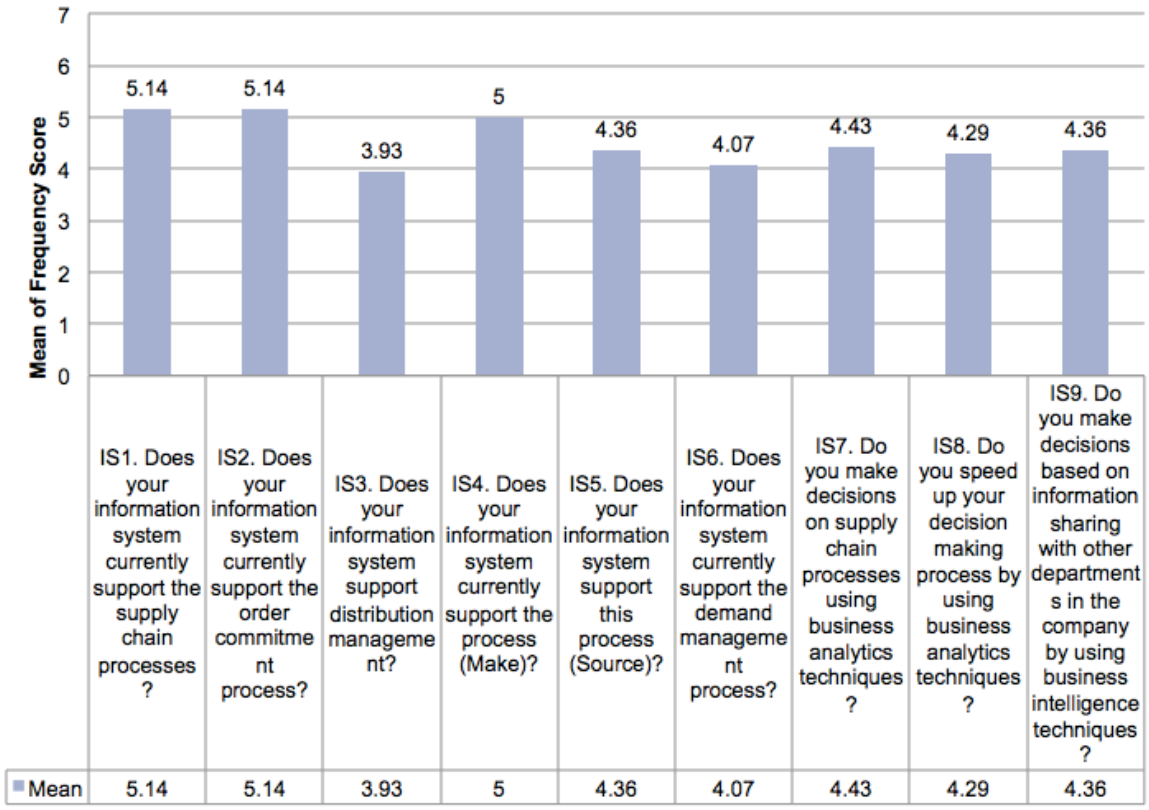

Figure 4.13. Mean performance score in Information System support stage

Moreover, Figure 4.13 indicates all the mean frequency score for each individual indicator question. Question IS1 and IS2 received the higher average value and they are above 5, which means companies in this study more than frequently demonstrate that their information system can support their supply chain processes and order commitment. However, the mean value of IS3 shows that companies' information systems in this study do not work in distribution management as other functions. Other indicators like the support of Make, Source processes, demand management, business analytics, decision-making processes, sharing with other departments in the companies.

4.3.6. Overall Performance

Table 4.6

Descriptive performance score in Overall Performance

Statistic	P12. Overall, the Plan process area performs very well.	S6. Overall, the Source process area performs very well.	M8. Overall, the Make process area performs very well.	D7. Overall, the Delivery process area performs very well.	IS10. Overall, information systems support the supply chain processes very well.
Min Value	3	4	3	4	4
Max Value	7	7	7	7	7
Mean	5.07	5.00	5.07	5.29	5.29
Variance	1.15	1.08	1.61	0.99	0.99
Standard Deviation	1.07	1.04	1.27	0.99	0.99
Total Responses	14	14	14	14	14

The overall performance of the survey respondents was informed by questions about four areas in the SCOR model and information system support performance based on these four areas. Table 4.6 shows the minimum, maximum and mean self-assessment values, variance, and standard deviation in the total 14 sample participants. The standard deviation actually seems smaller than other stages. The lowest one was 1.02 for Question P12, and the highest one was 1.27 for Question S6. All the mean values in the Overall performance section were larger than 5, which means the information system and BI techniques frequently perform well for these companies and participants in terms of their supply chain performance. According to Figure 4.13, the highest performance was for statement D7 and IS10. That is to say, participants think their information system and BI techniques are more likely to help their Delivery and supply chain processes well. The

variance of the overall performance between different stages was not obvious. In this study, participants tended to agree their information systems are beneficial to their supply chain performance.

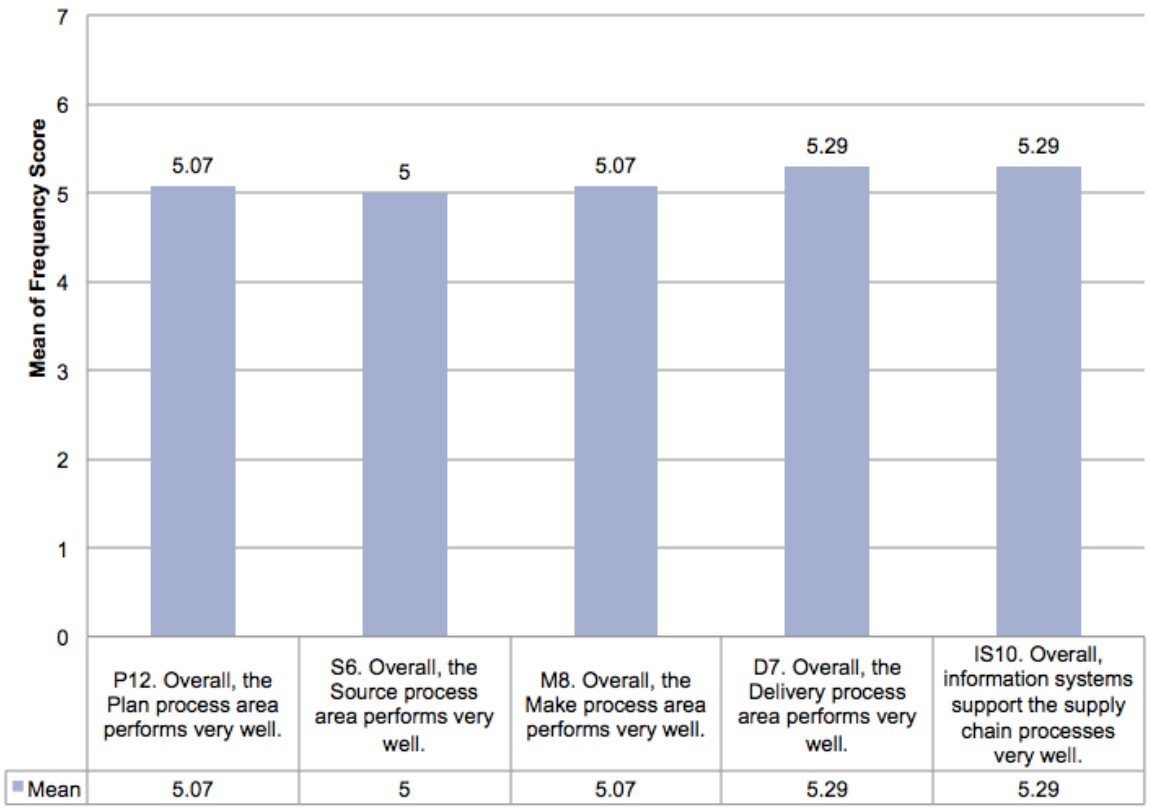

Figure 4.14. Mean overall performance score

4.4 Pearson's Correlation

In order to see the relationship between all the indicator factors including SCOR areas with the overall supply chain performance, a Pearson's correlation test was conducted to calculate the p value and the correlation parameter in total 14 samples. According to Table 4.7, the Pearson correlation was 0.585 and the significance is 0.028.

Since the cutting value assumed in this study was 0.1, the significance was smaller than the cutting value and the correlation was positive. Thus, in this study, the results showed that the impact of information systems and BI techniques support was positive on the supply chain performance. In order to explore different areas of the SCOR model to help figure out the influence of different measurement indicators by information system support, another Pearson correlation test was conducted. Table 4.8 indicated that all the correlation was positive but the significance varies. The significance for Plan stage was 0.133 and it was more than 0.1, which means the Plan stage has no significant effect on the supply chain performance. The significance for Source, Make, Delivery and information system support were all smaller than 0.1, which means they all had enough effect on the overall performance in 14 participants.

Table 4.7

Correlation between overall supply chain performance and all factors

	All factors
Pearson Correlation	0.585
Sig	0.028
N	14

Table 4.8

Correlation between overall supply chain performance and SCOR individual areas

	Plan	Source	Make	Delivery	Information system
Pearson Correlation	0.422	0.57	0.506	0.486	0.558
Sig	0.133	0.033	0.066	0.078	0.038
N	14	14	14	14	14

4.5 T-test Analysis between Different Groups

A T-test was performed to detect the difference between different groups of participants. In this study, the survey questionnaire has divided participants' work experience into 1-3 years, four-five years and more than 5 years. Because the four-five year sample was very small, this t-test only detected the difference between 1-3 years and more than 3 years to see if the performance and indicator assessment results vary due to the years of work experience. For this study, the p value for the t-test was 0.05. From Table 4.9, it showed all the p values were larger than 0.05. Thus, there was no significant difference in the survey results between different years of work experience. Another group of people were selected by different industries. In this study, most of the participants' company came from manufacturing and IT industries. Thus, a comparative analysis between manufacturing and IT industries was performed. Table 4.10 shows the same results as the work experience. There is still no significant difference of the results between these two industries. Then, the user experience of BI was divided into beginner, intermediate and advanced levels. Because the advanced levels only had a very small

sample, a comparison analysis using t-test was performed to see the difference between beginners and intermediate level of BI technique users. The results also indicated the same conclusion. There was no significant difference between these samples in terms of the familiar use experience of BI techniques. The results might change if the sample size were larger.

Table 4.9

Statistical analysis between work experience with 1-3 years and more than 5 years

	1-3 years		More than 5 years		T test
	Mean	SD	Mean	SD	P value
Plan	4.25	1.12	4.67	0.94	0.48
Source	4.34	2	4.27	1.2	0.94
Make	4.08	1.23	4.38	1.41	0.69
Delivery	4.52	1.49	5.06	1.5	0.54
Information System	4.92	0.96	4.02	1.8	0.27
Overall Performance	5.2	0.67	4.83	1.05	0.46

Table 4.10

Statistical analysis between manufacturing and IT industries

	Manufacturing		IT		T test
	Mean	SD	Mean	SD	P value
Plan	4.86	0.98	4.03	0.93	0.15
Source	4.89	1.37	3.87	1.81	0.27
Make	4.86	1.04	3.81	1.27	0.13
Delivery	4.06	1.49	4.56	1.64	0.84
Information System	4.95	1.07	4.61	0.87	0.55
Overall Performance	5.2	1.1	5.13	0.85	0.91

Table 4.11

Statistical analysis of BI user between beginner and intermediate levels

	Beginner		**Intermediate**		**T test**
	Mean	SD	Mean	SD	P value
Plan	4.6	1.13	4.15	1.11	0.51
Source	4.46	2.31	3.8	1	0.57
Make	4.29	1.27	4.14	1.61	0.87
Delivery	4.9	1.4	4.47	1.45	0.61
Information System	5.21	0.82	3.84	1.79	0.10
Overall Performance	5.34	0.83	4.88	0.64	0.32

4.6 Different BI Vendors and Products Comparison

This research compared different BI vendors and their products. In this case, according to the survey questionnaire, all the participants indicated different BI platforms and information system that they use in their companies. Table 4.12 showed the participant order and their answers related to this topic. For example, Participant 1 used SAP, Microsoft and IBM products. Participant 2 only used IBM products. Participant 3 did not use SAP, Microsoft and IBM products.

Table 4.12

Participant orders divided by the use of SAP, Microsoft, and IBM products

	Sap	Microsoft	IBM
1	x	x	x
2			x
3	x	x	
4		x	x
5	x	x	x
6		x	x
7		x	x
8	x	x	x
9			x
10	x	x	
11	x	x	
12		x	
13			
14		x	

Figure 4.15. Mean performance score in different areas between BI vendors

Figure 4.15 indicated the performance of each SCOR areas and overall supply chain performance between three different vendors that all the 14 participants assessed. Results showed SAP performs the best in each section, and Microsoft ranks the second, but the IBM was better than Microsoft from an information system support standpoint. Overall, these three BI vendors were relatively weak on Source and Make sections in BI techniques compared to other SCOR stages. Yet, all the three seemed stable from Plan to Delivery.

4.7 Summary

This chapter described various qualitative and quantitative data analysis and results used for the purpose of this study. Tables and Figures are visual tools to demonstrate the results. The next chapter addresses discussion, conclusion and recommendations for future research.

CHAPTER 5. DISCUSSION

This chapter presents the summary of the research results and further discussion related to the research topic. It also provides a conclusion to this study and recommendations for future studies.

5.1 Summary of the Survey Results

From the qualitative results of the survey, participants all have some business intelligence experience in their work experience. Most of them are beginner and intermediate. Some of them are at an advanced level. Their positions are wide ranging - from junior analysts to directors and they are the representatives from various departments in their organizations including traditional supply chain related such as logistics and supply chain department, and purchasing and sourcing departments. Some of them are from engineering, manufacturing, quality, new product introduction and sales departments. Yet, even though they are from different departments in the companies, 100 percent of these participants agree that business intelligence software and techniques are beneficial to their organizations to some extent. Most of them state that BI can be considered a long-term business strategy level or as a critical success factor that can help determine the organization's success. A small amount of participants think BI can somewhat help productivity and decision making processes on that Operations level. Also

order fulfillment, new product introduction, and lean facilitator; three of them were junior analyst; others were one senior analyst, one associate and one director

in this study, the participants' responses reflected on three BI vendors including SAP, IBM and Microsoft. It can be understood that these three companies are all considered among the biggest information technology companies in the world and they are famous for their BI systems and solutions.

The survey responses also showed that Microsoft Excel/Access Analytics still has the largest share of users compared to other BI tools. It can be seen that Microsoft Excel/Access is still popular and has been applied to different types of data analysis including business intelligence. Almost every department in an organization has access to Microsoft Excel/Access, which really helps users to share information with each other. Another finding is that Dashboard and SAP Business Objects and Predictive analysis are frequently used as well. Dashboard helps to visualize data for users for making decisions based on different performance indicators or real time data from different sources. SAP is widely used in the enterprise resources applications field. Half of the participants in this study have experience in the use of SAP Business Objects or Predictive helps analysis, even if the information system in their companies are not mainly SAP. It means that SAP BI tools have good extension capabilities. The analysis of results also illustrated IBM Cognos has a certain amount of users but is not used as widely as Microsoft and SAP. In fact, Cognos is the first vendor that applies with production style reporting and business query reporting. Participants who have the experience of Cognos usually have the IBM information system for their companies. It might indicate the Cognos does not have very

good extension to other platforms. Yet, Cognos is more specifically focused on business intelligence and performance management as a part of IBM solutions.

Speaking of the quantitative part of this study, the survey was collected based on SCOR benchmark model including four areas – Plan, Source, Make and Delivery. Due to the requirement of the research, all the participants selected in this survey are coming from companies that have global supply chains. This allows the SCOR model to be referenced the most because companies that possess global supply chains usually tend to have complex supply chain systems and need large amounts of data analysis. In this way, the effects of BI techniques can be easily detected from the results at different SCOR areas.

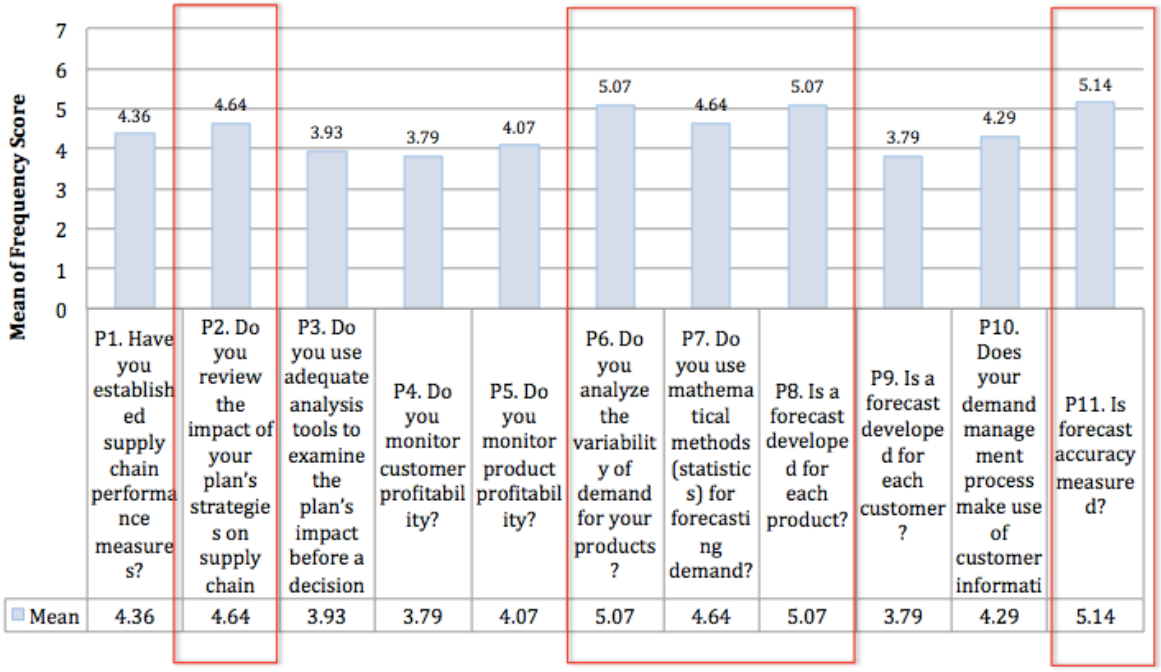

Figure 5.1. Significant mean performance score in Plan stage

In Figure 5.1, the red square highlighted those indicators in the Plan stage passed significant test based on the mean value and standard deviation in a seven point Likert scale. In the Plan area, the results showed that companies in the study usually review the impact of their Plan strategies on supply chain, and analyze the variability of demand for their products by using BI tools. They applied statistical analysis to forecast demand and develop forecasting methods for each product. Another finding was that participants' companies often measured the forecast accuracy. After reviewing the demographical background descriptions in the previous chapter, the results showed people from IT department didn't frequently examine the strategies and their impact on supply chain. Yet, most of the participants' work involved statistical analysis and forecasting for their companies' products. In this way, companies can apply BI to see how many products they need to produce and how many materials they need to purchase from their suppliers. However, as is visible in the results, companies may have some concerns about the use of BI in forecasting demands for each customer and examining the Plan's impact before a decision is made.

In Figure 5.2, the red square highlighted those indicators in the Source stage that passed the significance test based on the mean value and standard deviation in a seven point Likert scale (Vagias, 2006). In the Source area, the results illustrated companies in the study usually documented their supplier inter-relationships, and share planning and scheduling information with their suppliers. Combining with the demographical background descriptions in the previous chapter, the results showed people from IT department seemed not as familiar with the BI applications in the Source area and people with more years' work experience tend to have a higher frequency of information

documentation and sharing. Also, according to participants' responses, BI can be improved by adding more features such as enhanced collaboration with suppliers in developing a plan.

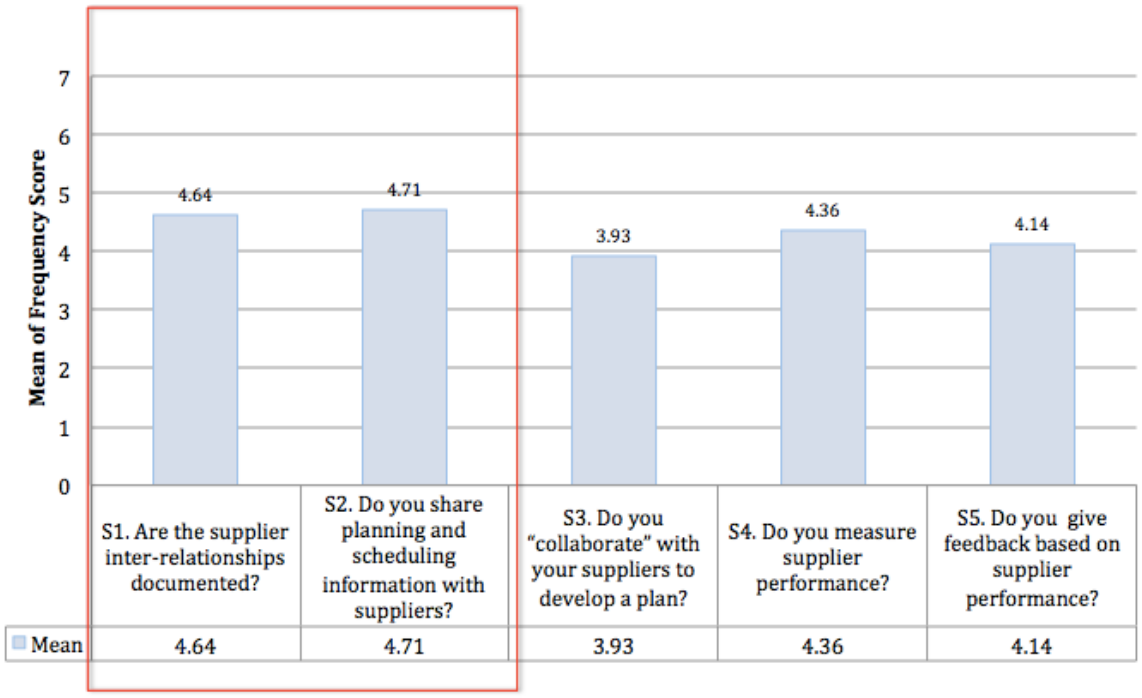

Figure 5.2. Significant mean performance score in Source stage

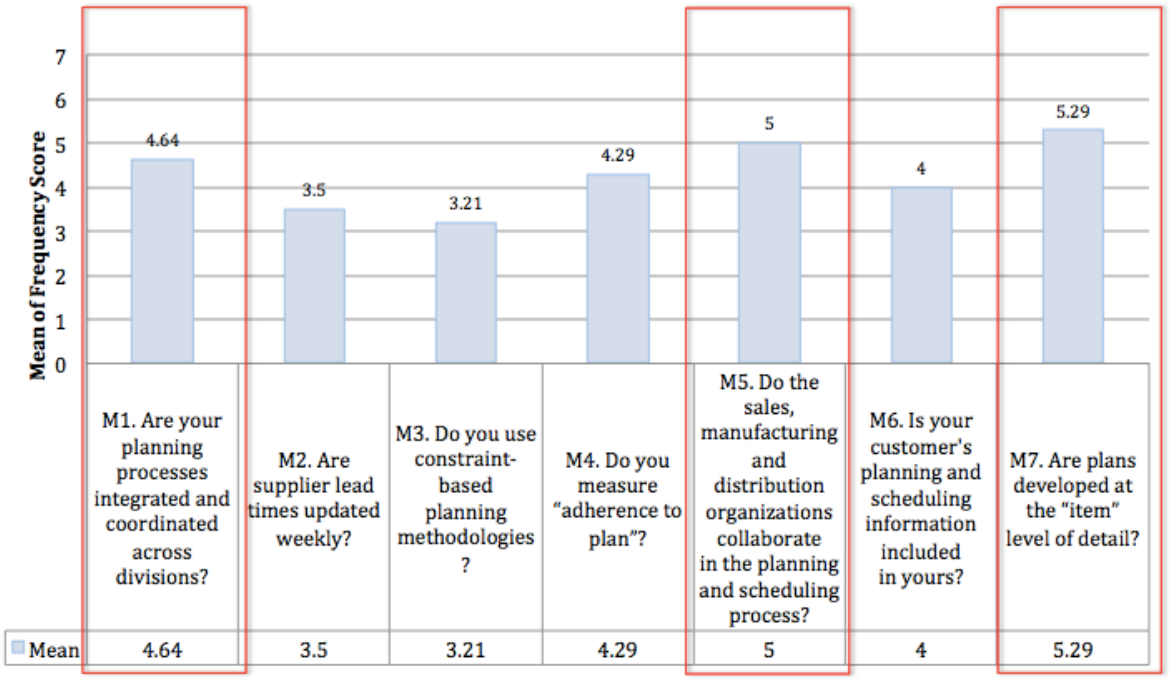

Figure 5.3. Significant mean performance score in Make stage

In Figure 5.3, the red square highlighted those indicators in the Make stage that passed the significance test based on the mean value and standard deviation on a seven point Likert scale. In the Make area, the results illustrated BI is usually good at integrating different processes, performance measuring, collaborating with sales, manufacturing and distribution departments, and making item-based detailed plans. Combining with the demographical background descriptions in the previous chapter, the results showed people from IT industry usually don't have manufacturing processes, so their Make scores are all lower than participants from manufacturing industry. Participants with less work experience might not be familiar with the whole operation processes in the companies in detail. For those participants with more than five years' work experience, most of them gave a high frequency score in the Make stage. However, participants think BI tools in their companies could be improved upon by updating

supplier lead time more frequently, using constraint-based planning methodologies, and connecting customers' planning and scheduling information.

In Figure 5.4, the red square highlighted those indicators in the Delivery stage that passed the significance test based on the mean value and standard deviation on a seven point Likert scale. In the Delivery area, the results collected showed that BI techniques in the participants' company exceled at tracking the order delivery on time and measuring out of stock situations. Also, participants agreed that BI techniques were used sometimes for interrelationships management, mathematical tools to assist in distribution planning, distribution performance management and process measurement with recognized process participants. After reviewing the demographical background descriptions in the previous chapter, the results showed Participant 1's company was not strong in the Delivery stage, although they already used three vendors' products. Possible technology adoption and communication problem between departments may have influenced the results in the Delivery stage. According to these participants' response, the results overall showed BI techniques need more development for collaboration between different parties and different measurement situations.

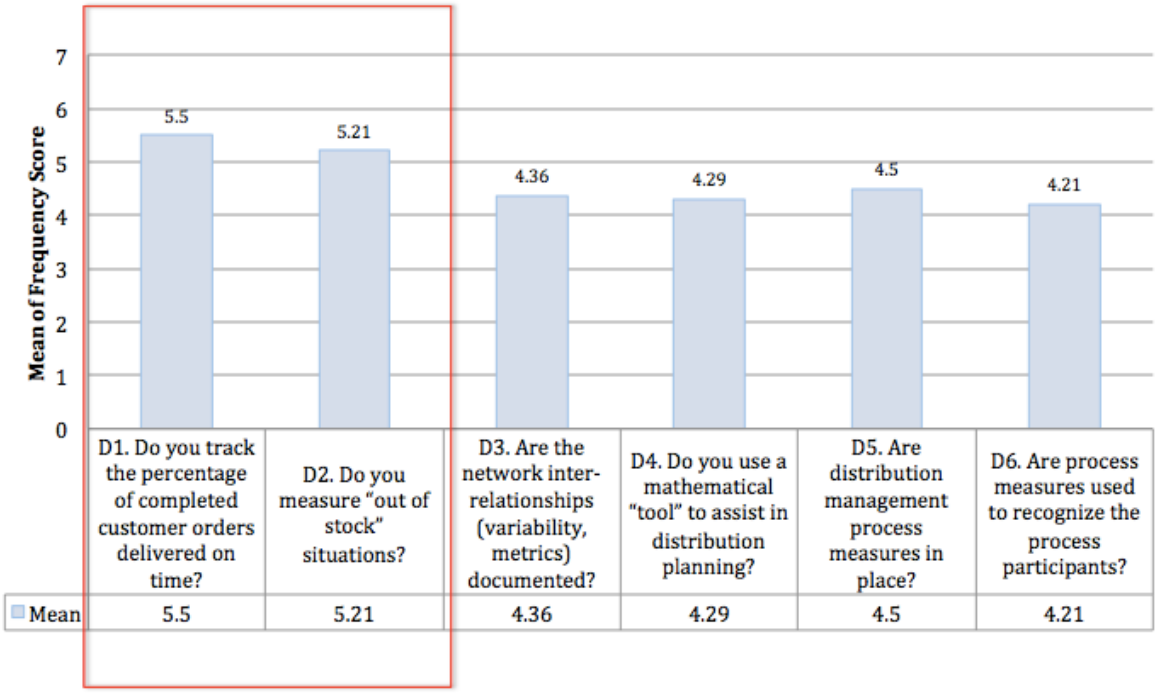

Figure 5.4. Significant mean performance score in Delivery stage

In Figure 5.5, the red square highlighted those indicators in the information system support passed the significance test based on the mean value and standard deviation on a seven point Likert scale. For the support of information system, it can be seen in the results that participants usually agree that information systems are beneficial for their supply chain processes, and offer support for the order management and manufacturing processes. Also, the support of information system is frequently applied in the Source processes and business analytics with decision-making processes. The results found that participants agree that their information system and BI techniques can speed up their decision-making process by using business analytics and making decisions based on the information sharing with other departments. After reviewing the demographical background descriptions in the previous chapter, the results showed participants from IT industry with more work experience usually have high frequency score in most indicators

of information system support in this study. Most of the results were higher than other SCOR areas. Yet, participant 7's company should improve their information system to support their supply chain. Also, information systems involved in the study are not strong at supporting distribution management and demand management compared to other supply chain processes.

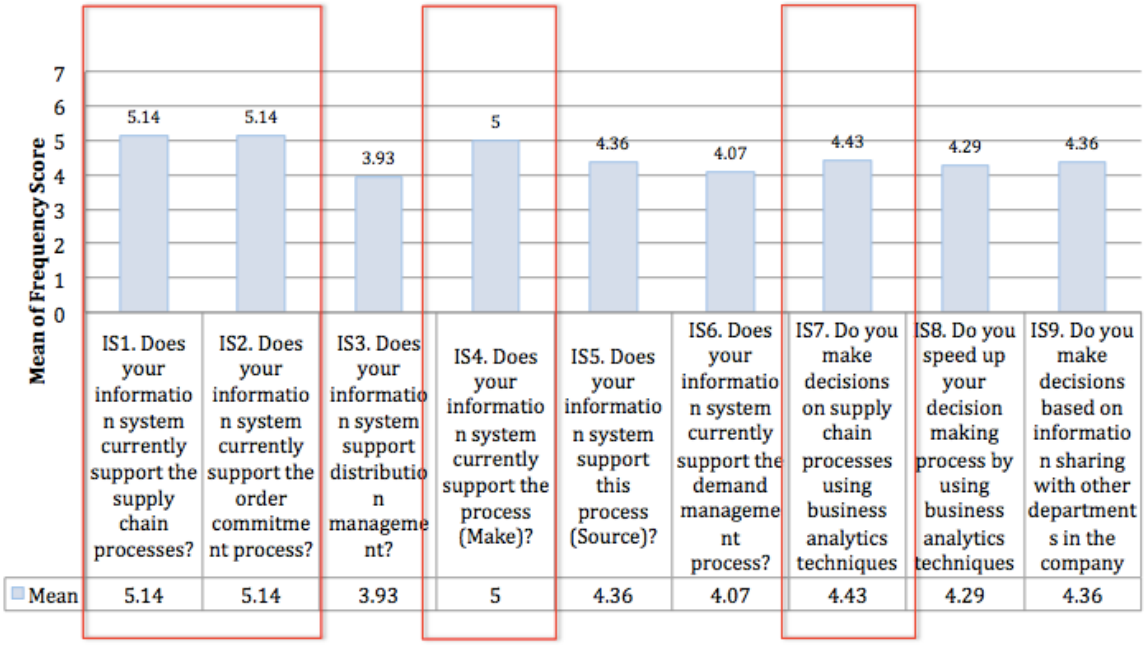

Figure 5.5. Significant mean performance score in information system support

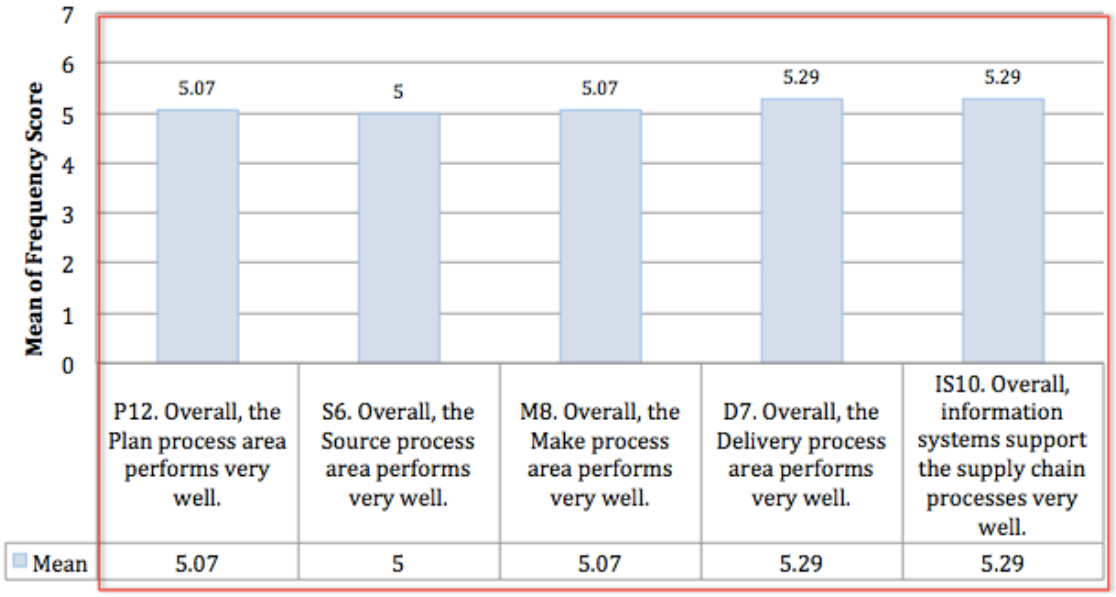

Figure 5.6. Significant mean performance score in overall performance

Figure 5.6 illustrated that all the statements in the overall performance passed the significance test. Participants all agree their information systems and BI techniques can support the supply chain performance through Plan, Source, Make, and Delivery. Participants including participant 1, 3, 6 and 10 from the manufacturing industry in different departments tended to strongly agree that their company's overall performance in SCOR areas and information system support is associated well with the use of business intelligence software and their current information systems. Yet, the results implied it is hard for people to implement the information technology to support different areas in the processes. The overall performance is well supported, but the participant companies' current BI techniques and software still had limitations in some levels. According to the SCOR benchmark, they lack chances to measure and analyze some information that are beneficial to their supply chain performance. In this situation, those companies may

consider arranging more training for their employees or looking for other BI products to support these relatively weak elements.

From a supply chain standpoint, there is a gap between Plan, Source, and Make processes. The results showed the Plan score is higher, but the Source and Make is always lower than the other scores, and the overall performance is around the average area. That is to say, business intelligence techniques and information systems can do a good job of planning, scheduling, forecasting but they still need work on more sections and details for Source and Make stages. At least the participants in this study did not have strong knowledge about the use of BI in these two levels. It is important to see that these indicators were built well in the leading BI platforms and products including SAP, IBM and Microsoft.

According to results of the correlation test, it showed that the support of BI techniques and information system does have a positive impact on the supply chain performance. With regard to different SCOR stages, the use of BI and information system in Source, Make and Delivery can be beneficial for the overall supply chain performance with a cutting value of 0.1. However, the use of BI and information systems in the Plan stage does not indicate a strong effect on the overall performance in this study. That could potentially be caused by the gap between Plan and other stages. From the data in chapter 4, it can also be seen that the score for plan is higher than all other stages according to the opinions of all the participants. It might be explained that people tend to have plans more than executions and plans may be hard to follow if the Plan itself has problems. Apparently, in this study, BI techniques and information systems are

developed well in the Plan stage but need more work in the gap between the Plan and other operation processes.

Furthermore, from the data shown in previous chapter, the standard deviation is a bit large for a seven point Likert scale. Some of the data variation may result from a lack of information flow between different departments in the organizations. For example, an engineering employee may not know supply chain processes very well so they can't understand how BI techniques would be used in the same organizations because they probably do not use BI to purchase materials from suppliers. A deficit of information is a very typical reason to explain why all the indicator values fluctuated and varied to such an extent. Also, the benchmark indicators have their own limitations in representing all of the companies. Various companies could employ a variety of supply chain formats and conditions, notwithstanding their use of different information systems and BI products. Additionally, different companies have their own cultures and ways of doing business to operate on a daily basis. It is hard to detect all the factors that could influence the results of the survey. Yet, this is also why this study applies SCOR benchmark to detect the supply chain performance in each company. SCOR is an industry benchmark and can be modeled in a general way. Even if the model may be fit with all the detailed operational processes in the companies, all these indicator questions can still detect the current situations in these companies.

A t test analysis was conducted to see the difference of the survey results between different divisions of participants. From the results, all three groups have no significant difference within each group at a p-value of 0.05. The results of the participants who have one to three years' work experience found no big difference from those having more

than five years' work experience. The results of the participants who are from manufacturing companies also found no big difference from those are from an information technology companies. Also, the results from the participant who are BI technique beginners identified no big difference from those who are at BI technique intermediate level. However, if the sample size of this study were larger, the results might be changed. It is always interesting to see if there is any significant difference between various BI users from various parties with various experiences.

Moreover, a comparative graph with different performance values in Plan, Source, Make, Delivery, information system support and overall performance was shown to find which BI vendor received the higher score. The results showed that SAP was better at all the SCOR stages and its information systems supported them pretty well so the overall performance of companies that use SAP was higher than those using Microsoft and IBM. Microsoft still works well for most of the SCOR stages, but its support from information system to supply chain processes was not reported to be as good as IBM. However, IBM BI analytics was still not very strong with respect to certain supply chain processes compared to SAP and Microsoft products in this study. Possible solutions to get a higher performance score might be that a company can use a combination of different information system and BI tools. In this way, more information can be collected from various sources and installed in different data warehouse. With the help of all the connections of these data warehouse and BI solutions, the supply chain can get more collaboration and comprehensive analysis with a larger amount of data from different departments. A combination of BI tools from different vendors might assist them to make up for each other. The results from this study suggested this possibility. Participant 1,

Participant 5 and Participant 8's companies uses a combination of SAP, IBM and Microsoft products together and their overall supply chain performance ranked the highest over other participants in the participants' self-assessment.

5.2 Current BI Techniques and Discussion

After the market analysis and the academic sources review, it is not hard to find that business intelligence is popular and has a huge variety of options, solutions, and features in the market. Some of them are really intelligent and have a relatively complete business solution for various industries and companies. Companies like SAP, IBM, Microsoft and Oracle all have good, organic business systems. Their products cover data warehouse, data mining, query and reporting, enterprise resources planning system, performance management, business intelligence analytics tools and platforms, web based development tools, various data visualization methods, etc. Some BI examples could be Dashboards, Scorecard, Query reporting and predictive analytics. All these could be supportive for each SCOR area and work with different scenarios because the purpose of business intelligence is to improve information quality and make better decisions. For instance, Microsoft's products can fit many companies and industries because most of their products can be customized and the price is not overly expensive for small to mid size companies.

However, some challenges for current BI tools can be seen as the following. First, every time a new employee comes in, he/she always needs training on the use of the information system and the business intelligence techniques. Especially for those companies who have a variety of BI tools without training, those new users may not have

a good knowledge of places to mine data, where the data is stored, which data they can access and where to find other data from other departments or hidden places. Second, if the BI system is built for various industries, it may lose detailed functions which are useful for each individual industry or company because each company may have its own unique operation processes and business scenarios. If an information system has many features and can be fitted to most of the companies, it might become excessively complex and complicated for small companies because some of the processes might be too detailed or some of processes might not be suitable for their companies at all. Also, the additional complexity may lead to ambiguity and difficulty for newer users attempting to learn. For instance, SAP is a complex system with lots of modules and product varieties. It is also famous for its not so user-friendly interface. Third, the development of business intelligence should be along with the development of data visualization as well. It is awkward if someone uses advanced techniques to analyze a huge dataset and then does not know how to explain the results to people. It also decreases the effects of BI if the data visualization capabilities are limited. Various forms of data visualization should be developed and customized by each customer, supplier, product, process, plan, and performance measurement from the standpoint of supply chain management. It could be a big challenge, but also an opportunity for future business intelligence development. Fourth, communication is always a problem for the use of any technology. From this study, it is obvious that the information system can improve the information sharing and flow at some point but still it is hard to convey data from one department to another department, from one process to another process, or from one party to another party. Without human interpretation and communication, data is just numbers with no greater

meaning. As long as the communication improves, the BI users can understand the business concern and situation more clearly, and then make a better decision on what data to select and analyze, as well as how they can address the proper person in a appropriate manner. It might have huge influence on the effect of business intelligence techniques in supply chain performance or operations processes.

5.3 Conclusion

This study was mainly focused on examining the effect of the use of business intelligence techniques in supply chain performance based on the performance measurement system by using SCOR benchmark model including the areas of Plan, Source, Make, and Delivery. The study evaluated both the qualitative and quantitative data through an online survey. The results of this study represent responses from companies belonging to manufacturing and information technology industries. Three main BI vendors and their products were compared and investigated in this study. The effectiveness of business intelligence techniques was assessed by participants across different departments in different supply chain processes in each individual company. Also, the results from this study indicated that the use of business intelligence techniques and information systems does influence the supply chain and it is beneficial to the supply chain performance. In addition, the results found there was no significant difference between the respondent self-assessment scores between individual participants from various years of work experience, various industries and various experience with BI. Furthermore, the results showed that a combination use of BI techniques and information system from different vendor may cause an increase of the overall supply chain

performance of the organization. Compared with IBM and Microsoft, SAP runs the best on the whole supply chain process for the participants' companies in this study. This study also reflected participants' opinions about current situations of business intelligence techniques and potential challenges in the future. In conclusion, this study helps in identifying the influence of business intelligence techniques on overall supply chain performance within a few companies across different departments. It also compared BI vendors and their products including SAP, Microsoft and IBM and the results are suggestive of things to be improved for future development.

5.4 Recommendations for future studies

For future studies, it would be interesting to determine if the results change by increasing the sample size of this survey with a more diverse and larger group of people. With the time constraints, this study could not be conducted to investigate the same survey questions over a long term within the same company. Open-ended questions with personal interviews might also be helpful for a more detailed understanding of the use of the business intelligence tools. Further usability tests could also be performed to see how different BI products vary from others within a relatively same testing environment. In addition, due to the limitations of the sample, this study did not cover detailed performance and effectiveness measurement for Oracle's products. Oracle, as another BI leading company, has a huge variety of BI products and customers from diverse industries as well. In the future, it would be valuable to compare the use of Oracle's BI techniques and solutions with SAP, Microsoft and IBM's

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APPENDICES

Appendix A

Recruitment Letter

Dear Participant:

My name is Jue Gu and I am a graduate student at Purdue University. For my thesis research, I am examining the use of business decision-making analytical tools (also called Business Intelligence techniques) and its influence on the supply chain processes by applying SCOR benchmarks (Supply Chain Operations Reference model produced by Supply Chain Council). It involves various levels of performance metrics - plan, source, make, and delivery**.** The survey aims to investigate companies in the U.S. involved in global supply chains. I am inviting you to participate in this research study by completing the short survey attached to this letter.

The following survey was developed to ask you a few questions regarding the above topic. It is our hope that the results of this research will benefit you and your company to understand the effects of Business Intelligence techniques on supply chain performance in terms of different key performance indicators and financial influence. If you choose to participate, I promise to send the executive summary (about 1-2 page) to you after I complete the research. There are no identified risks associated with participating in this research.

The survey is confidential and anonymous. Participation is strictly voluntary and you may refuse to participate at any time. You will receive no monetary compensation for participating in the research study. The survey will take approximately **15-25 minutes** to complete.

Further information regarding the research can be obtained from the principal researcher. Thank you for your consideration. Your help is greatly appreciated!

Appendix B

Linkedin Post

Hello everyone! I am a graduate student at Purdue University. For my thesis research, I am examining the use of Business Intelligence techniques and their influence on supply chains by applying SCOR benchmarks. I invite you to participate in my study by completing a short survey (approximately 15-25 minutes).

It is my hope that the results of this research will benefit your company, showing the effects of BI on supply chain in terms of different KPIs and financial influence. If you choose to participate, I promise to send the executive summary (about 1-2 pages) to you after completion. There are no identified risks associated with participating in this research. The survey is entirely confidential and anonymous. Further information regarding the research can be obtained from me. Your help is greatly appreciated!

Appendix C

IRB Approval & Amendment Approval

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	KATHRYNE NEWTON YONG
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	03/31/2014
Committee Action:	**Exemption Granted**
IRB Action Date:	03/31/2014
IRB Protocol #:	1401014399
Study Title:	The use of business intelligence techniques in supply chain performance

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b)(2) .

If you wish to make changes to this study, please refer to our guidance "**Minor Changes Not Requiring Review**" located on our website at http://www.irb.purdue.edu/policies.php. For changes requiring IRB review, please submit an **Amendment to Approved Study** form or **Personnel Amendment to Study** form, whichever is applicable, located on the forms page of our website www.irb.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	NEWTON, KATHRYNE A
From:	DICLEMENTI, JEANNIE D, Chair Social Science IRB
Date:	05 / 07 / 2014
Committee Action:	Amended Exemption Granted
Action Date:	05 / 07 / 2014
Protocol Number:	1401014399
Study Title:	The use of business intelligence techniques in supply chain performance

The Institutional Review Board (IRB) has reviewed the above-referenced amended project and has determined that it remains exempt.

If you wish to make changes to this study, please refer to our guidance"**Minor Changes Not Requiring Review**" located on our website at http://www.irb/purdue.edu/policies.php. For changes requiring IRB review, please submit an **Amendment to Approved Study** form or **Personnel Amendment to Study** form, whichever is applicable, located on the forms pages of our website www.irb.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

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- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit

Appendix D

Qualtrics Survey Questions

.
This survey is going to examine the use of business decision-making analytical tools (also called Business Intelligence techniques) and its influence during the supply chain processes by applying SCOR benchmarks (Supply Chain Operations Reference) model produced by Supply Chain Council, which has the most authority in the field.

This model describes different levels of performance metrics through four phases: plan, source (supply), make (manufacture), and delivery. This survey aims to investigate company's use of this in the United States involved in global supply chains.

The following survey was developed to ask you a few questions regarding the above topic. It is our hope that the results of this research will benefit you and help your company to understand the effects of Business Intelligence techniques on supply chain performance in terms of different key performance indicators and financial influence. There are no identified risks from participating in this research.

The survey is confidential and anonymous. It will take approximately 15-25 minutes to complete.

Thank you for your time!

Survey Completion
0% 100%

>> Next

. What is your contact information?

Survey Completion
0% 100%

<< Previous >> Next

***Q1.* What is your gender?**

- Male
- Female

Survey Completion
0% 100%

<< Previous >> Next

Q2. What is your position?

- ◯ Junior Analyst
- ◯ Senior Analyst
- ◯ Associate
- ◯ Manager
- ◯ Director
- ◯ Other (Please specify)

Survey Completion
0% 100%

<< Previous >> Next

Q3. What is your department?

- ◯ Marketing
- ◯ Sales
- ◯ Purchasing & Sourcing
- ◯ Information Technology
- ◯ Logistics & Supply Chain
- ◯ Quality
- ◯ Engineering
- ◯ Manufacturing & Production
- ◯ Other (Please specify)

Survey Completion
0% 100%

<< Previous >> Next

Q4. What industry does your company belong to?

- ◯ Manufacturing
- ◯ Electronics
- ◯ Retail
- ◯ Logistics
- ◯ Distribution
- ◯ Information Technology
- ◯ Other (Please specify)

Survey Completion
0% 100%

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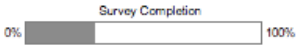
Q5. How many years of industry experience do you have?

- ◯ less than 1 year
- ◯ 1 to 3 years
- ◯ 4 to 5 years
- ◯ more than 5 years



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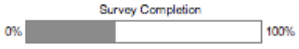
Q7. Does your company involve global supply chain?

- ◯ Yes
- ◯ No



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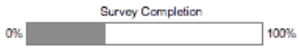
Q6. Does your work involved in database?

- ◯ Yes
- ◯ No



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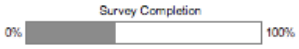
Q7. Does your company involve global supply chain?

- ◯ Yes
- ◯ No



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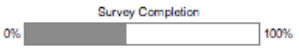
Q8. Have you ever worked with Business Intelligence (BI) softwares or techniques?

BI includes data mining, statistical analysis, data visualization tools, dashboard, data warehouse, data loading, data transforming, data exacting, etc

- ◯ Yes
- ◯ No



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***Q9.* How familiar are you with Business Intelligence softwares or techniques?**

- ◯ Beginner
- ◯ Intermediate
- ◯ Advanced
- ◯ Expert

Survey Completion
0% 100%

<< Previous >> Next

***Q10.* How could you categorize the use of Business Intelligence softwares and techniques in your organization?**

- ◯ It is a critical success factor; influences the whole organization's success
- ◯ It supports business strategy; influences the achivement of strategy over a long period
- ◯ It has promoted minor improvements; influences business processes on a daily basis
- ◯ It helps us maintain our current platform; has not had a major influence on operations
- ◯ It has decreased productivity; had a negative influence on the speed of our operations

Survey Completion
0% 100%

<< Previous >> Next

***Q11.* What information system vendors have been used in your company?**

- ☐ SAP
- ☐ Oracle
- ☐ IBM
- ☐ Microsoft
- ☐ Other (Please specify)

Survey Completion
0% 100%

<< Previous >> Next

***Q12.* What Business Intelligence techniques have been used in your work?**

- [ ] Dashboard Analytics
- [ ] SAP Business Objects/Predictive Analysis
- [ ] Microsoft Excel/Access Analytics
- [ ] Other (Please specify)

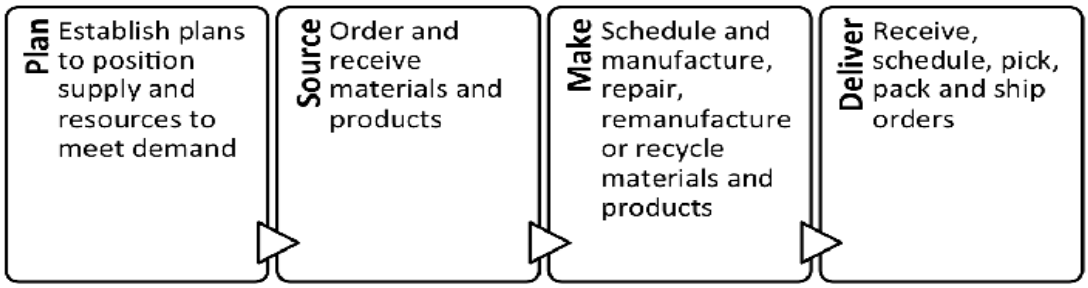
Survey Completion
0% 100%

<< Previous >> Next

.

The following questions are all based on your personal assessment of the use of the Business Intelligence Techniques in four phases below.

Below shows the Supply Chain Operations Reference model phases: PLAN, SOURCE, MAKE, DELIVERY. (Taken from https://supply-chain.org/scor)



Survey Completion
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Q14.
Indicators of analytics capabilities in SOURCE

Please answer the following questions using a seven point Likert scale (1 – Never; 2 – Rarely, in less than 10% of the chances; 3 - Occasionally, in about 30% of the chances; 4 – Sometimes, in about 50% of the chances; 5 – Frequently, in about 70% of the chances; 6 – Usually, in about 90% of the chances; 7 – Every time).

	Never (0%)	Rarely (<10%)	Occationally (30%)	Sometimes (50%)	Frequently (70%)	Usually (90%)	Every time (100%)
S1. Are the supplier inter-relationships documented?	○	○	○	○	○	○	○
S2. Do you share planning and scheduling information with suppliers?	○	○	○	○	○	○	○
S3. Do you "collaborate" with your suppliers to develop a plan?	○	○	○	○	○	○	○
S4. Do you measure supplier performance?	○	○	○	○	○	○	○
S5. Do you give feedback based on supplier performance?	○	○	○	○	○	○	○

Survey Completion
0% 100%

<< Previous >> Next

Q13.
Indicators of analytics capabilities in PLAN

Please answer the following questions using a seven point Likert scale (1 – Never; 2 – Rarely, in less than 10% of the chances; 3 - Occasionally, in about 30% of the chances; 4 – Sometimes, in about 50% of the chances; 5 – Frequently, in about 70% of the chances; 6 – Usually, in about 90% of the chances; 7 – Every time).

	Never (0%)	Rarely (<10%)	Occasionally (30%)	Sometimes (50%)	Frequently(70%)	Usually(90%)	Every time(100%)
P1. Have you established supply chain performance measures?	○	○	○	○	○	○	○
P2. Do you review the impact of your plan's strategies on supply chain performance measures?	○	○	○	○	○	○	○
P3. Do you use adequate analysis tools to examine the plan's impact before a decision is made?	○	○	○	○	○	○	○
P4. Do you monitor customer profitability?	○	○	○	○	○	○	○
P5. Do you monitor product profitability?	○	○	○	○	○	○	○
P6. Do you analyze the variability of demand for your products?	○	○	○	○	○	○	○
P7. Do you use mathematical methods (statistics) for forecasting demand?	○	○	○	○	○	○	○
P8. Is a forecast developed for each product?	○	○	○	○	○	○	○
P9. Is a forecast developed for each customer?	○	○	○	○	○	○	○
P10. Does your demand management process make use of customer information?	○	○	○	○	○	○	○
P11. Is forecast accuracy measured?	○	○	○	○	○	○	○

<< Previous >> Next

Q15.
Indicators of analytics capabilities in MAKE

Please answer the following questions using a seven point Likert scale (1 – Never; 2 – Rarely, in less than 10% of the chances; 3 - Occasionally, in about 30% of the chances; 4 – Sometimes, in about 50% of the chances; 5 – Frequently, in about 70% of the chances; 6 – Usually, in about 90% of the chances; 7 – Every time).

	Never (0%)	Rarely (<10%)	Occationally (30%)	Sometimes (50%)	Frequently (70%)	Usually (90%)	Every time (100%)
M1. Are your planning processes integrated and coordinated across divisions?	○	○	○	○	○	○	○
M2. Are supplier lead times updated weekly?	○	○	○	○	○	○	○
M3. Do you use constraint-based planning methodologies?	○	○	○	○	○	○	○
M4. Do you measure "adherence to plan"?	○	○	○	○	○	○	○
M5. Do the sales, manufacturing and distribution organizations collaborate in the planning and scheduling process?	○	○	○	○	○	○	○
M6. Is your customer's planning and scheduling information included in yours?	○	○	○	○	○	○	○
M7. Are plans developed at the "item" level of detail?	○	○	○	○	○	○	○

Survey Completion
0% 100%

<< Previous >> Next

Q16.
Indicators of analytics capabilities in DELIVERY

Please answer the following questions using a seven point Likert scale (1 – Never; 2 – Rarely, in less than 10% of the chances; 3 - Occasionally, in about 30% of the chances; 4 – Sometimes, in about 50% of the chances; 5 – Frequently, in about 70% of the chances; 6 – Usually, in about 90% of the chances; 7 – Every time).

	Never (0%)	Rarely (<10%)	Occationally (30%)	Sometimes (50%)	Frequently (70%)	Usually (90%)	Every time (100%)
D1. Do you track the percentage of completed customer orders delivered on time?	○	○	○	○	○	○	○
D2. Do you measure "out of stock" situations?	○	○	○	○	○	○	○
D3. Are the network inter-relationships (variability, metrics) documented?	○	○	○	○	○	○	○
D4. Do you use a mathematical "tool" to assist in distribution planning?	○	○	○	○	○	○	○
D5. Are distribution management process measures in place?	○	○	○	○	○	○	○
D6. Are process measures used to recognize the process participants?	○	○	○	○	○	○	○

<< Previous >> Next

Q17.
Indicators of information system support

Please answer the following questions using a seven point Likert scale (1 – Never; 2 – Rarely, in less than 10% of the chances; 3 - Occasionally, in about 30% of the chances; 4 – Sometimes, in about 50% of the chances; 5 – Frequently, in about 70% of the chances; 6 – Usually, in about 90% of the chances; 7 – Every time).

	Never (0%)	Rarely (<10%)	Occationally (30%)	Sometimes (50%)	Frequently (70%)	Usually (90%)	Every time (100%)
IS1. Does your information system currently support the supply chain processes?	○	○	○	○	○	○	○
IS2. Does your information system currently support the order commitment process?	○	○	○	○	○	○	○
IS3. Does your information system support distribution management?	○	○	○	○	○	○	○
IS4. Does your information system currently support the process (Make)?	○	○	○	○	○	○	○
IS5. Does your information system support this process (Source)?	○	○	○	○	○	○	○
IS6. Does your information system currently support the demand management process?	○	○	○	○	○	○	○
IS7. Do you make decisions on supply chain processes using business analytics techniques?	○	○	○	○	○	○	○
IS8. Do you speed up your decision making process by using business analytics techniques?	○	○	○	○	○	○	○
IS9. Do you make decisions based on information sharing with other departments in the company by using business intelligence techniques?	○	○	○	○	○	○	○

Survey Completion
0% 100%

<< Previous >> Next

***Q18.* PERFORMANCE**

Please rate the following statements using a seven point Likert scale (1 – Strongly disagree; 2 – Disagree; 3 - Somewhat disagree; 4 – Neither agree or disagree; 5 – Somewhat agree; 6 – Agree; 7 – Strongly agree).

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
P12. Overall, the Plan process area performs very well.	○	○	○	○	○	○	○
S6. Overall, the Source process area performs very well.	○	○	○	○	○	○	○
M8. Overall, the Make process area performs very well.	○	○	○	○	○	○	○
D7. Overall, the Delivery process area performs very well.	○	○	○	○	○	○	○
IS10. Overall, information systems support the supply chain processes very well.	○	○	○	○	○	○	○

<< Previous >> Next